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SIDE-LOBE CANCELLER ARRAY DESIGN DESCRIPTION

Contract Number W7714-5-9868

A Company of Intelligent Technology

Applied Silicon Inc. Canada

CONTRACT NUMBER W7714-5-9868

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Contract Number W7714-5-9868

Revision 1.0

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April 1996

Document #974-55126-07

SUMMARY

This document presents a detailed hardware and operational description of the Side-Lobe Canceller (SLC) Array. This array is one of two eight element arrays in the Experimental Array Radar System (EARS). It has eight standard gain horns oriented in a horizontal line using horizontal polarization. This report presents a short description of the EARS and how the SLC array is used in the system. The SLC is described in detail, beginning with a general description and continuing with more detailed information.

This document was prepared under task 6.3 of contract number W7714-5-9868. It covers a gap in the system documentation which has occurred since the SLC array was first designed and built in 1992. A major re-build of the array was done in early 1995, without documentation. The two original documents covering the SLC array have been used as the basis for this document, with updates and added information. A related document has been prepared covering the Calibration Control Mechanism (CCM). This is a frame with four radiators on it that is used to calibrate the SLC array. It is located immediately in front of the SLC array. The array horns are mounted on the rear of the CCM frame, in a rigid mount. The remainder of the array is mounted on a large plate which is located near the top of the front end platform equipment rack.

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1.0 INTRODUCTION

This document is a complete update and rewrite of two previous documents. It covers the design and interconnections for the Side-Lobe Canceller (SLC) Array, otherwise known as the horizontal array. The SLC array is one of two eight element receiving arrays in the Experimental Array Radar System (EARS). It was first designed and constructed in mid-1992, using components from an earlier array. In the spring of 1995 the complete array was moved from its original plate to a new plate and the physical configuration was completely changed. At the same time a calibration system was added. The calibration hardware is mounted on a rigid frame which is attached to the front end rack, directly in front of the eight SLC standard gain horns. Part of the calibration system, known as the Calibration Control Mechanism (CCM), is hinged and swings down when not in use so it does not block the horns. The CCM design and description is covered in other documents and will not be covered in this document.

The original SLC design document was written under DSS contract number W7714-1-9521 as is entitled;

SIDE-LOBE CANCELLER ARRAY DEVELOPMENT
SIDE-LOBE CANCELLER DESIGN

By John Curnow and Robert Moore, Applied Silicon Inc.
June 1992, version 1.2

The original SLC interconnection document was written under DSS contract number W7714-2-9604 and is entitled;

SIDE-LOBE CANCELLER ARRAY DESIGN
INTERCONNECTION DOCUMENT

By John Curnow, Applied Silicon Inc.
November 1992, version 2.0

These two reports have been used as the basis of this new document. Although much has changed, any material from these two documents that is still applicable has been used for this document. Only the SLC receiver array that is mounted on the front end turntable is covered, up to the main BNC output connectors from the mixers. The SLC 60 MHz IF receiver is described in other reports.

2.0 EARS DESCRIPTION

The EARS is an experimental radar system used for research into several areas including target height estimation, target tracking, main beam nulling and side-lobe nulling. It has been developed for over ten years and has gone through several major phases. It is based at a remote site

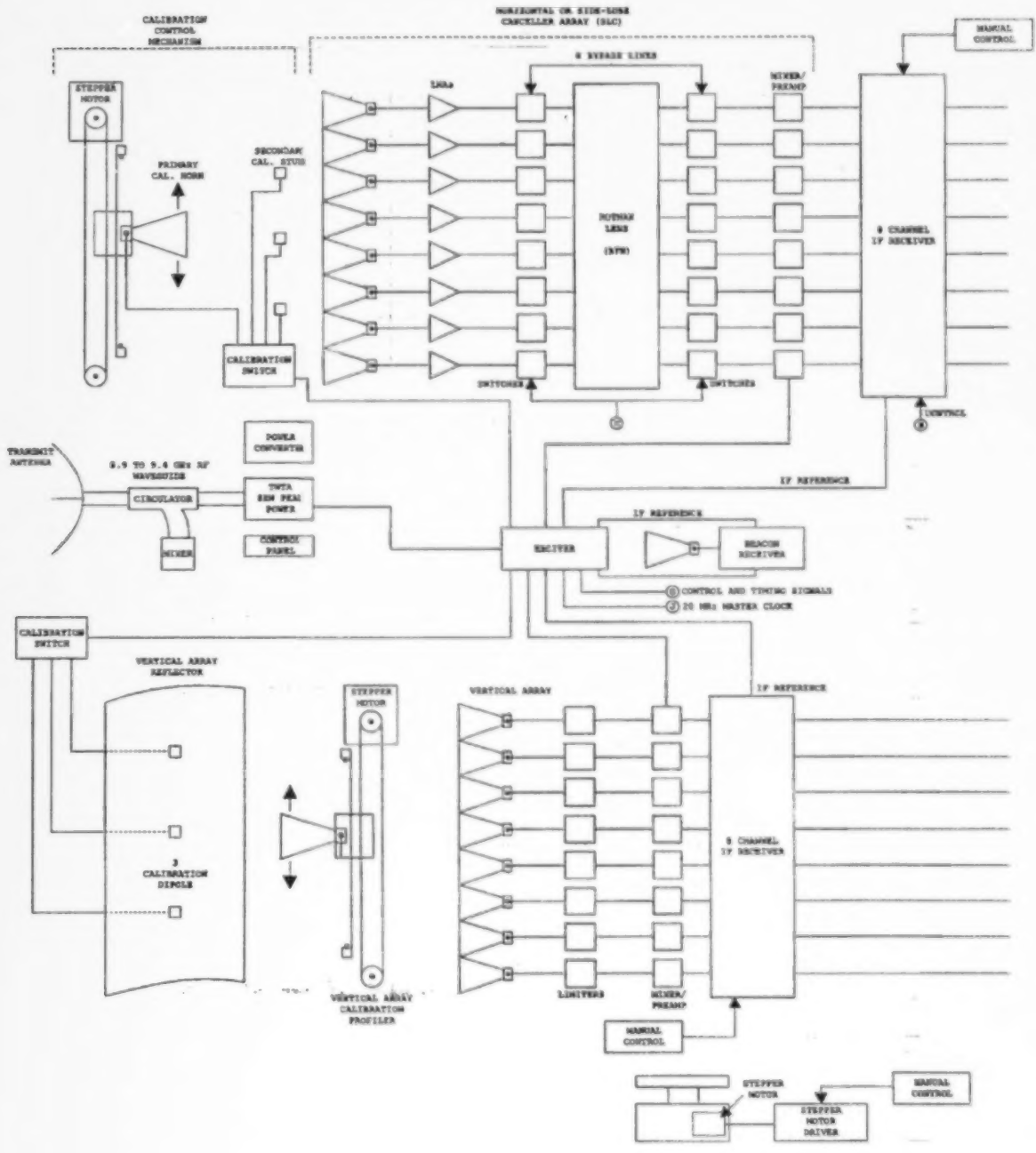


Figure 1

EARS Front End Block Diagram

of the Defence Research Establishment Ottawa (DREO) called 'Area Five', which is located on the Ottawa River. Figure One is a block diagram of the EARS. It has two eight element receiving arrays, the Vertical Array and the SLC, or Horizontal, Array. Each array produces 60 MHz intermediate frequency (IF) signals which are processed by two similar IF receivers. The down-converted IF receiver outputs are digitized at 20 megasamples per second and stored on a 13 gigabyte hard disk array. A ten meter long portable lab houses the 'back end' of the system. The system 'front end' is contained on a rack which is mounted on a turntable. The direction of the antennas is adjustable in azimuth with the turntable, but not in elevation. Twenty meter cables connect the two main parts of the system. The received RF signals are down-converted to the 60 MHz IF by mixers before they are sent to the lab over the long RG58 coaxial cables.

A front end unit called the Exciter is the source of the transmitted X-band signal and the local oscillator (LO) signals. It contains a highly accurate and stable 10.0 MHz oscillator which is used as the EARS base clock. All RF, IF and timing signals are phase locked to this source. The SLC array is mainly mounted on a single large plate, located near the top of the front end rack. The receiving horns are mounted on the CCM frame, directly ahead of the plate. Semi-rigid coaxial cables connect the horn outputs to the array low noise amplifiers (LNA).

The SLC array was first built when the EARS was known as the Experimental Low Angle Tracking (ELAT) system. The ELAT system used two 65 kilowatt peak power magnetrons and had a coherent on receive setup. The EARS is coherent on transmit since all the signals are phase locked to the 10 MHz source. A travelling wave tube amplifier (TWTA) amplifies the 8.90 to 9.40 GHz signal produced by a synthesizer in exciter. It is rated at eight kilowatts peak power. The EARS pulses the transmitted signal at a pulse repetition frequency (PRF) of 500 hertz to 25 kilohertz. The pulse widths are from two microseconds down to 200 nanoseconds.

3.0 SLC ARRAY GENERAL PHYSICAL DESCRIPTION

The array is composed of two main sections. The horns are mounted on the CCM frame and the rest of the array components are mounted on a single large plate located directly behind the CCM frame in the front end equipment rack. Figure two is a pictorial view of the CCM, with the primary calibration frame section in the deployed position. This can be compared to figure three which is a similar view of the CCM, except the primary section is folded in its storage position. This is the position that the frame would normally be in during operation of the SLC array. The CCM is deployed only when a primary calibration is done since it blocks the receive horns. The CCM frame is mounted on the platform equipment rack at three places. The three mounting bolts can most easily be seen in figure two, on the right side of the figure, which is the rear of the CCM frame. There are two upper bolts, one on each side, and a single lower bolt in the center. The mounting bolts are used to adjust the aim of the SLC horns with respect to the transmitting antenna and vertical array.

The eight SLC horns can be seen at the top rear of the CCM frame in figures two and three. They are mounted in a very rigid milled bracket, with the horn faces almost touching. The original bracket used to mount the horns was simply a bent piece of sheet aluminum and was not rigid or

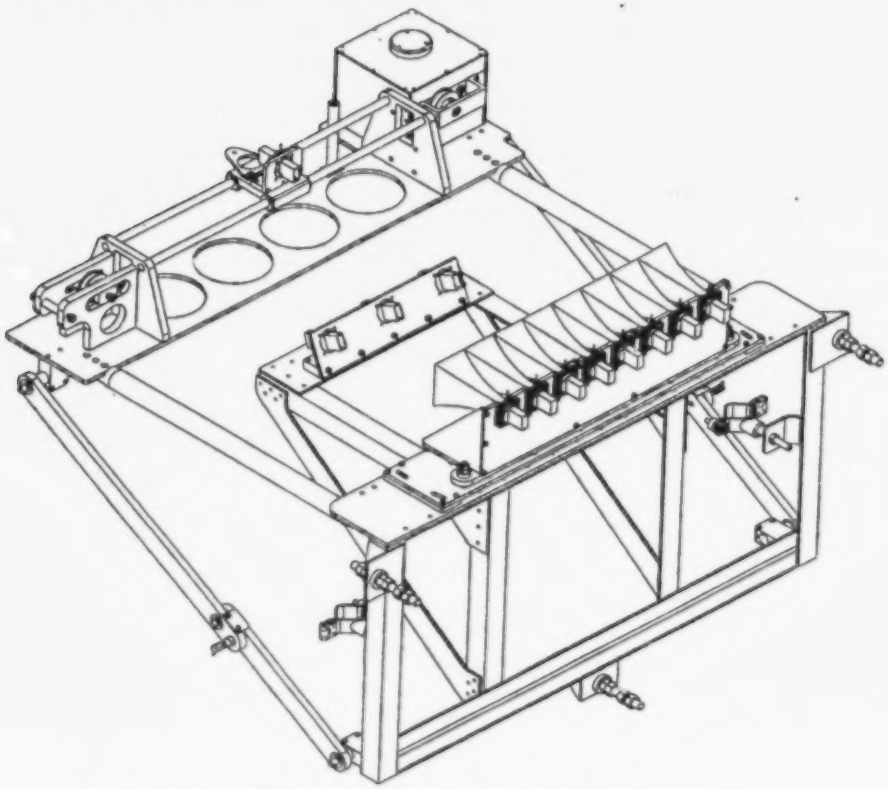


Figure 2 - Pictorial View of Deployed CCM

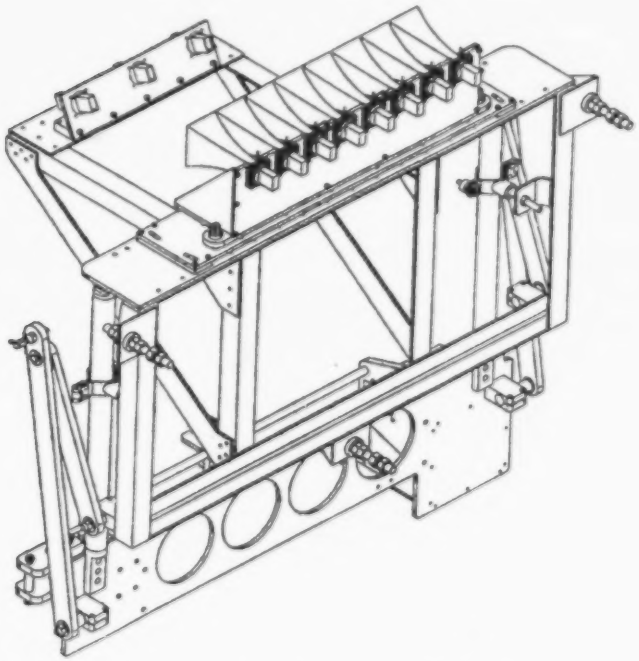


Figure 3 - Pictorial View of Stowed CCM

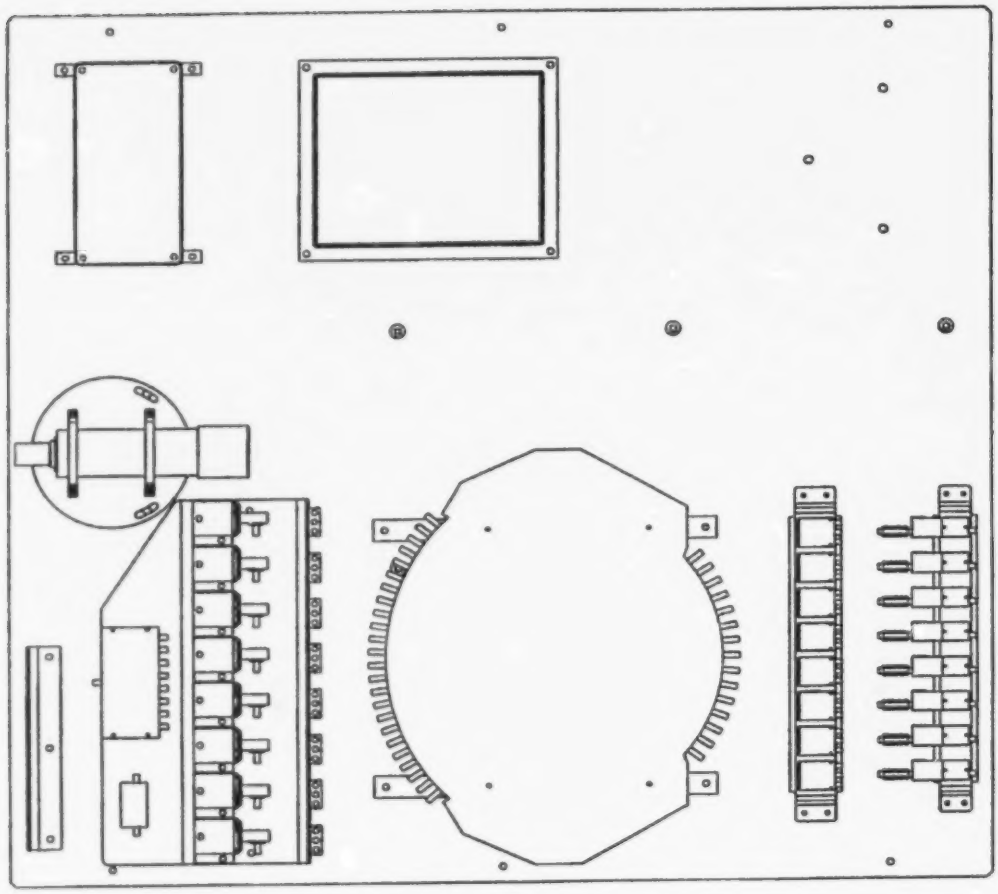


Figure 4

Overhead View of SLC Array Plate

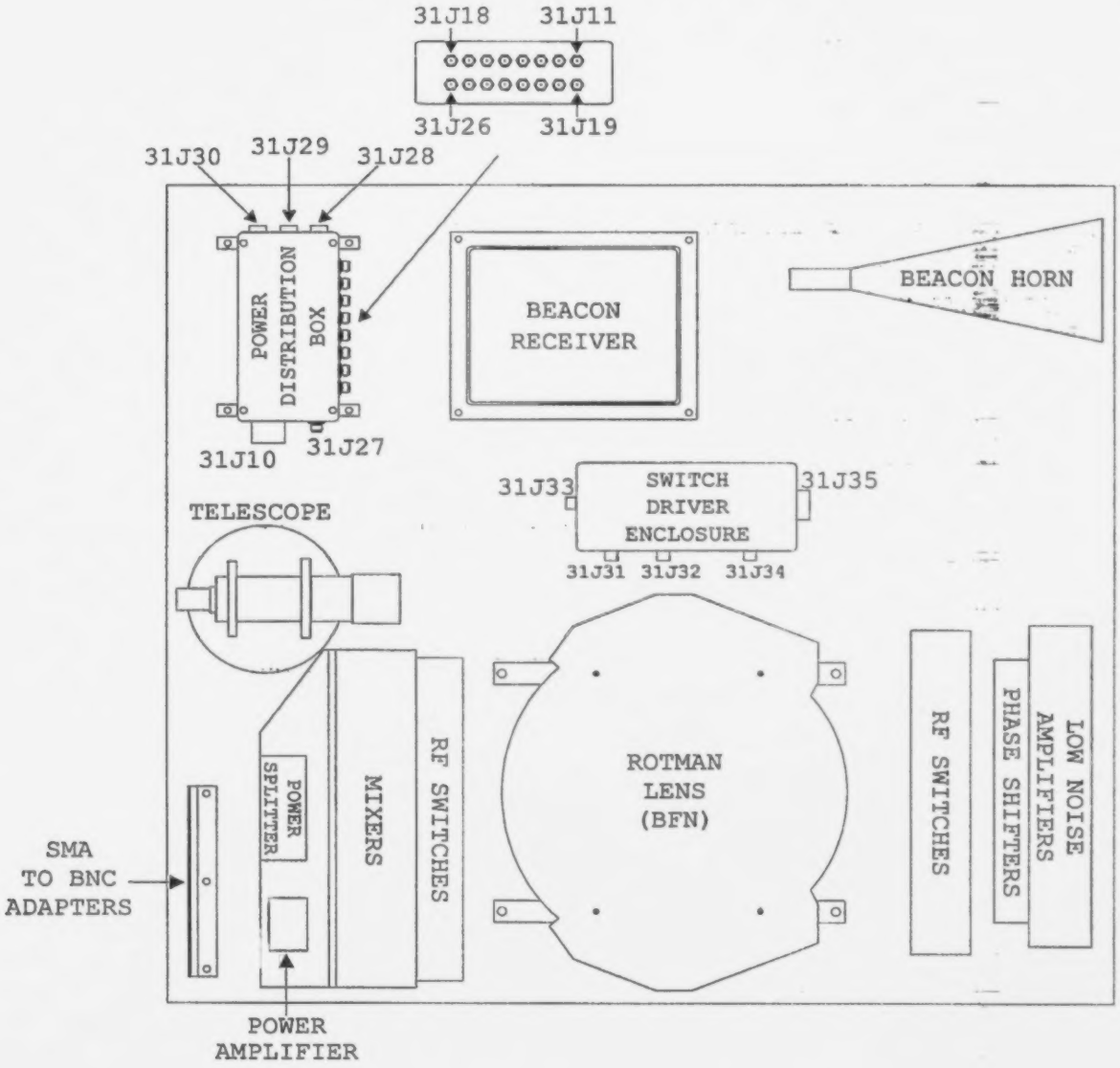


Figure 5

Component Layout on SLC Plate

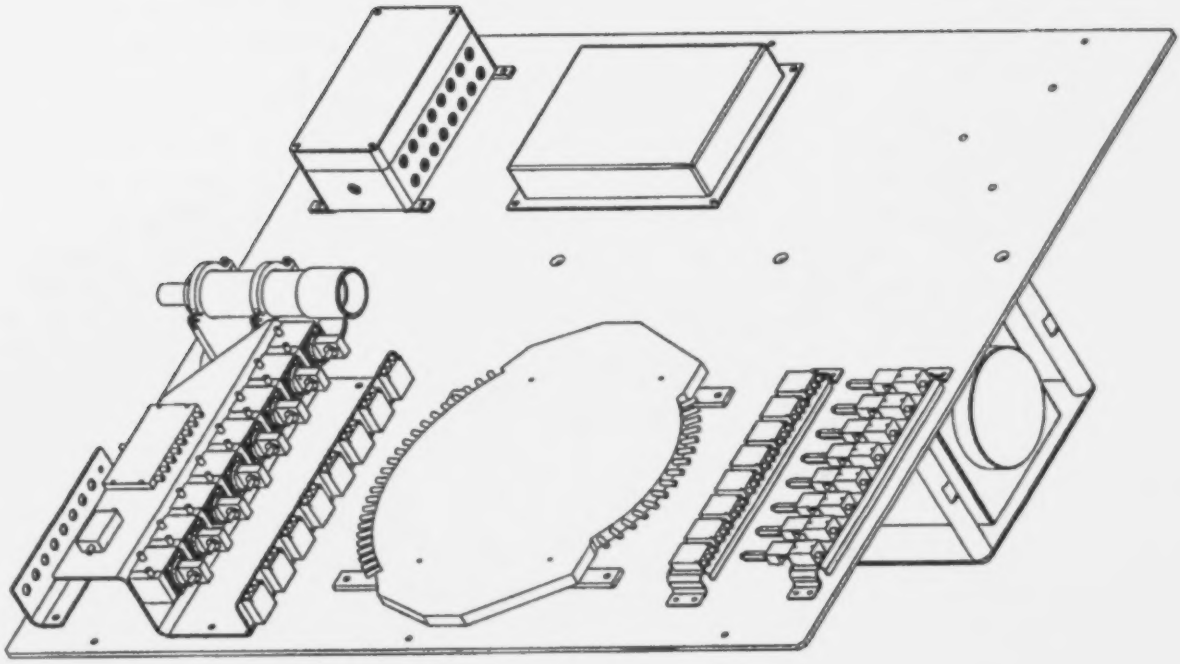


Figure 6

Pictorial View of SLC Array Plate

precise enough. The horns were mechanically aligned to within 0.002 inches and pinned in position. The gaps between the horn faces are not uniform because of the manufacturing variations in the horns. The actual receive elements in the waveguide to SMA transitions were used to align the horns, rather than the horn faces. In figures two and three the channels are numbered from one to eight, with channel one at the left of the diagrams.

Figure four is an overhead view of the SLC array plate. The rear of the rack is on the left and the horns are positioned on the right. Therefore, the received signal flow is from right to left. Figure five is a component layout diagram of the SLC array plate. The components have been identified on it. Figure six is a pictorial view showing the video camera mounted underneath the plate. The eight low noise amplifiers can be seen at the lower right. They are mounted on a raised bracket with the phase shifters mounted directly to the backs of the LNAs. A similar bracket holds the first group of eight coaxial switches. The large object in the lower center of the diagrams is the beam forming network (BFN). It is attached to the plate with four legs. The numerous input and output SMA connectors can be seen. A large bracket made of folded aluminum plate holds the second group of switches, the mixers, the local oscillator amplifier and the LO splitter. The switches are secured vertically to the front of the bracket, with their SMA connectors pointing up. The mixers can be seen directly behind the switches. The waveguide to SMA transitions are mounted on the front of the mixers. At the rear center of the bracket the eight-way LO splitter can be seen. Beside it is the LO amplifier. The bracket at the left lower rear of the diagrams is for the SMA to BNC chassis connectors. Eight connectors are for the IF outputs and one is for the local oscillator input. These connectors are not shown in figures four and six.

The power distribution box is in the upper left corner. The holes for the SMA connectors can be seen in figure six, although the connectors themselves are not shown. The large flat box beside the power distribution box is for the beacon receiver electronics. The beacon horn is not shown for clarity, although it would normally be mounted in the blank space on the upper right of figures four and six. It is mounted on a sheet aluminum bracket which is attached to the plate using the three holes in the plate. Its aim is adjustable because there are three slots in the mounting bracket, rather than three fixed holes. The visual spotting scope is mounted in the center rear of the SLC plate. It is held securely by two wrap-around brackets and a mounting base. Slots in the mounting base allow the aim of the scope to be adjusted, in a fashion similar to the beacon horn. None of the power, control or signal cables are shown, for clarity.

4.0 SLC ARRAY DETAILED DESCRIPTION

4.1 Standard Gain Receive Horns

The SLC array has eight identical channels, with the receive horns oriented in a horizontal line. Figure seven is a block diagram of a single SLC array channel. All the component interconnections from the horns to the mixer/preamps use 0.141 inch semi-rigid cables and SMA connectors for the RF signals.

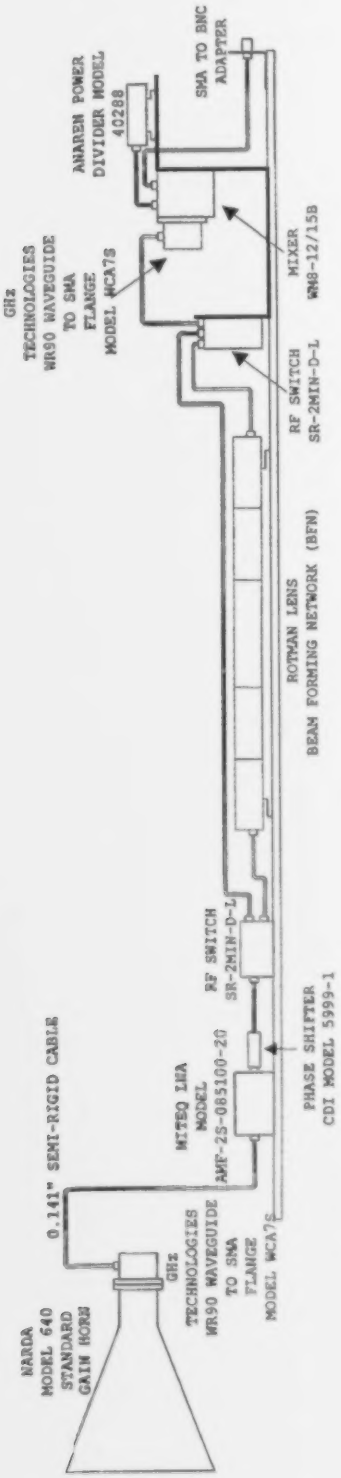


Figure 7
Block Diagram of Single SLC Array Channel

The SLC antenna array is composed of eight Narda model 640 standard gain horns. The specifications for these horns can be found in Appendix A. They have a nominal gain of 15 dBi. They are mounted in a horizontal row, as close as mechanically possible, using horizontal polarization. A WR90 waveguide flange to SMA coaxial transition is used on each horn. They are model number WCA7S (A5162-1) adapters, built by GHZ Technologies Inc.

4.2 Low Noise Amplifiers

The first component in the signal chain mounted on the array plate is the low noise amplifier (LNA). A piece of 0.141 inch semi-rigid cable connects the horn to the LNA, using SMA connectors. The LNAs are model AMF-2S-085100-20, by Miteq Inc. A sample test sheet is in Appendix A. The two most important specifications are the gain and the noise figure. The gain over the 8.5 GHz to 10.0 GHz range is no less than 19.6 decibels. The noise figure over this frequency range is no greater than 1.8 decibels, although it is typically less than 1.4 dB. In the SLC array configuration the LNA dynamic range is about 74.5 dB (see section 6.3). The output power capability is a minimum +10 dBm. The noise figure of the SLC front end is determined primarily by the LNAs. Their main function is to increase the gain, decrease the noise figure and to compensate for the loss caused by the BFN.

The following table gives the tested gains, noise figures and output powers at the one decibel compression point for each of the eight LNAs, tested at 9.0 GHz and 25 degrees Celsius. The gains and noise figures vary with the frequency and temperature. The gains drop and the noise figures increase as the frequency increases. The LNAs are rated for 8.5 GHz to 10.0 GHz and can operate from -40 to +60 degrees Celsius.

LNA Tested Gain, Noise Figure and
Power Output Specifications

SLC Channel	Serial Number	Gain (dB)	Noise Figure (dB)	Power Out @ 1 dB comp. (dBm)
1	244494	20.3	1.26	14.4
2	244495	20.9	1.29	15.4
3	244496	20.3	1.25	14.8
4	244497	20.6	1.25	15.3
5	244498	20.8	1.23	14.0
6	286126	20.7	1.38	14.0
7	244500	20.4	1.31	14.4
8	286125	20.8	1.28	14.5

4.3 Phase Shifters

Phase imbalances exist between the front end channels due to component tolerances and line length differences. To null out the phase differences, small phase shifters are used between the LNAs and the beam forming network. They are physically attached to the output SMA connectors of the LNAs. The phase shifters are CDI model 5999-1 phase adjustable SMA connector types. They work by allowing an adjustment of the line length, thus changing the relative phase. At a frequency of ten gigahertz the maximum adjustment range is 49 degrees. Section 7.0 describes the procedure used for adjusting the phase shifters. They are intended to phase balance the channels when the BFN has been switched out. There is no practical way to phase balance the channels when the BFN is in the system. The semi-rigid cables that connect to the phase shifter outputs are looped to allow the freedom of movement required for the complete adjustment range of the shifters.

4.4 BFN Coaxial Switches

When the array was first built, the BFN was physically connected or disconnected using semi-rigid cables. Two complete sets of semi-rigid cables were used. One set connected the inputs and outputs of the BFN into the array. The other was used to bypass the BFN, so the phase shifters were connected directly the mixer/preamplifiers. This scheme was very cumbersome since it took about half a day to switch the cable sets. It was prone to phase imbalances and could not be properly calibrated. To correct this deficiency, sets of RF switches were added to the array plate. Eight switches, one for each channel, are between the phase shifters and the BFN inputs and another set of eight switches are between the BFN outputs and the mixer/preamps. The switches are a single pole double throw configuration. In one position the BFN is in the SLC array. When in the other position, the BFN is electrically removed from the array. Two TTL control signals determine the positions of all sixteen switches in parallel, through an interface board. The board is contained in its own enclosure. The switches are manufactured by RLC Electronics Inc., model SR-2MIN-D-L and use a nominal 28 VDC control voltage. The specifications for the 4 to 12.4 GHz range are; maximum insertion loss 0.2 dB, maximum VSWR 1.3:1, minimum isolation 70 dB, maximum switching time 15 mS, break before make operation. Appendix A contains the manufacturer's data sheets.

4.5 Beam Forming Network

The BFN is a Rotman lens. It has fifteen inputs, or beam ports, and 24 outputs, or array ports. In the SLC array every second input is used, for a total of eight channels, and every third output channel is used. The width and spacing of the beam patterns depend on which inputs and outputs are selected. The BFN is a large circuit board of planar construction using bonded stripline technology with SMA connectors at all the inputs and outputs. It is connected in the SLC array to give eight beam directions with a null in the center. Each of the eight outputs is a phased combination of all the inputs. Both the inputs and outputs create beams in a symmetrical pattern about the fore-aft centerline, or 'Z' axis. The unused inputs and outputs are terminated in fifty ohms. The entire array direction is steered in azimuth using the lens. Figure eight is a plot of the theoretical

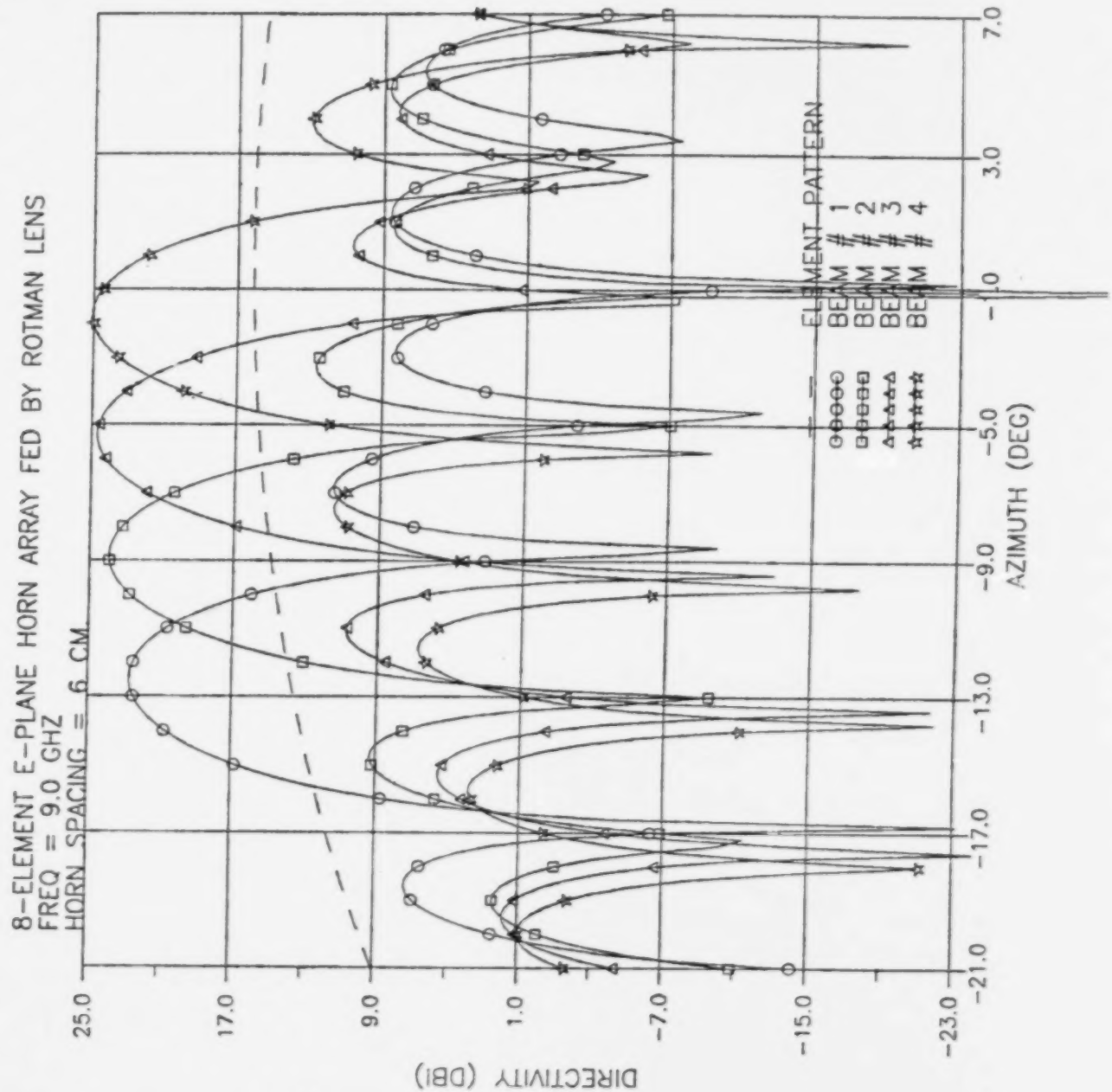


Figure 8

Theoretical BFN Beam Patterns

beam patterns created at four of the eight used outputs at 9.0 GHz. In the SLC array, the BFN has been connected to yield eight output beams, equally spaced from +12.7 degrees to -12.7 degrees. Zero degrees is defined as the peak of the transmitting antenna response. The following illustrates the theoretical positions of the beam peaks.

-12.70	-9.07	-5.44	-1.81		+1.81	+5.44	+9.07	+12.70	degrees relative to
|	|	|	|	0°	|	|	|	|	TX peak
1	2	3	4		5	6	7	8	SLC channel number

The BFN has the following design specifications.

Bandwidth	8.5 GHz to 10.0 GHz
Scan Coverage	±45 degrees maximum from broadside
Maximum Port VSWR	2.0:1
Insertion Loss	-10.0 dB maximum, any active input to all outputs
Crossover Level of Beams	< -4 dB from adjacent beam maximums
Array Element Spacing	6 cm, center to center
Array Port Amplitude Taper	within 6 dB window for any beam position
Connectors	SMA end-launch jack
Physical Dimensions	49.2 cm wide
	40.3 cm deep
	1.7 cm high

The board has been sandwiched between two aluminum plates for mechanical protection, with labels milled on the top plate to identify the connections. The labels number the inputs from 1 to 15 and the outputs from 1 to 24. These numbers are not related to the numbers assigned to the ports by the designer, K.K. Chan. The following table shows the SLC array numbering assignments. The BFN numbers are those assigned on the top aluminum plate. The channel numbers match the usual SLC channel numbers, from one to eight.

SLC INPUT CHANNEL	BFN INPUT PORT NUMBER	SLC OUTPUT CHANNEL	BFN OUTPUT PORT NUMBER
8	15	8	23
7	13	7	20
6	11	6	17
5	9	5	14
4	7	4	11
3	5	3	8
2	3	2	5
1	1	1	2

4.6 Orthoguide Mixer/Preamplifiers

The mixer/preamp inputs are connected to the BFN outputs. They are made by RHG, model number WM8-12/15B, and are a double-balanced orthoguide type. The RF input is via a WR90 waveguide flange and the IF output uses an SMA connector. The same type of waveguide to SMA transition is used on the mixers that is used on the horns. The mixers were first used on the original vertical array from the earliest experimental Area Five radar system. They were salvaged from that array and adapted for use in the EARS by changing the IF from 30 MHz to 60 MHz. They were sent back to RHG for this modification. RHG made the modifications and tested the mixers. The following specifications were taken from the RHG tested specification sheets.

WM8-12/15B Mixer/Preamplifier Tested Specifications at 10 GHz

SLC Channel	Serial Number	RF to IF Gain (dB)	Noise Figure (dB)	LO to RF Isolation (dB)
1	16-559-2	23	6.6	25
2	16-559-3	23	6.2	23
3	16-559-4	23	6.3	24
4	16-559-6	23	7.3	27
5	16-559-7	23	6.6	23
6	16-559-8	23	6.9	29
7	16-559-9	24	7.1	24
8	16-559-10	24	6.3	24

4.7 Local Oscillator Amplifier and Splitter

The local oscillator from the exciter is amplified by a Miteq model AMF-4B-089094-50-26P power amplifier. The tested gain of this amplifier is 25.4 decibels and the noise figure is 4.45 dB at 9.15 GHz. The complete specifications can be found in Appendix A. The output of the amplifier goes to an eight-way splitter, or power divider, Anaren model 40288. Both devices are mounted on the horizontal plate section of the bracket that holds the mixers, near the rear of the SLC plate. The input level to the amplifier is -8.0 dBm and the amplifier output is +17.4 dBm. The loss through the power divider is about nine decibels, therefore, the input level at each mixer is +7.8 dBm. This is well within the recommended level for these mixers.

The main IF connector plate is located behind the local oscillator amplifier and splitter, at the rear corner of the SLC plate. The connector plate holds nine BNC to SMA bulkhead connectors. Eight connectors are for the IF outputs and one is for the local oscillator input from the exciter.

The visual spotting scope is mounted at the rear of the SLC plate, on the left-right center line of the plate. This was the most convenient place to put the scope, although it has nothing to do with the functioning of the SLC array. The beacon reference enclosure and beacon receiver horn are also

mounted on the SLC plate, as shown in figure five, although they have no direct relationship to the function of the SLC array.

4.8 Power Distribution

There are many active devices on the SLC plate. A single power distribution enclosure box handles the power lines for all the active devices on the plate, including the power for unit four, the beacon receiver enclosure. All the required voltages are input to the plate via connector 31J10, a seven pin circular military type connector. The power distribution enclosure contains terminal strips which are used to distribute the power to all the active devices. It does not contain any active devices itself. This box replaces the previous power splitter box.

There are 17 SMA connectors mounted on the sides of the enclosure. One, 31J27, is for the local oscillator amplifier +15 VDC power. 31J11 through 31J18 distribute the +12 VDC to the eight mixers. 31J19 through 31J26 distribute the +15 VDC to the eight low noise amplifiers. RG178 coaxial cable is used for each of the seventeen SMA power connections. The coaxial cables are used for shielding purposes only.

Three other MS type connectors are mounted on the end of the power distribution box. 31J28 is for the +15 and +12 VDC power monitor connections to the system monitor. 31J29 is for the power output to the switch driver enclosure and 31J30 is for the beacon receiver power. The box is a NEMA 4 enclosure, with a rubber gasket. It is mounted near the rear of the SLC plate, beside the spotting scope.

4.9 Switch Driver Enclosure

The BFN switch driver board is contained in the switch driver enclosure. It is mounted near the center of the SLC plate, beside the BFN. This enclosure has five MS type connectors on it. Figure 9 is the schematic of the switch driver board. It contains six identical circuits to drive the BFN switches and CCM calibration radiator relay. Each circuit uses a 74LS04, 74LS06 and TIP101 transistor to convert an input TTL level control signal to the 24 VDC signal required by the switches and relay. The TTL control inputs come from the LCIU via connectors 34J31 and 31J32. Power for the board is input using connector 31J33. 31J34 outputs the switch controls to all sixteen BFN switches. Each switch requires two control lines. For proper switch operation one control line must be high while the other is low. 21J35 outputs the controls for the CCM calibration switch.

5.0 SLC ARRAY INTERCONNECTIONS

This section replaces the previous SLC interconnection document. Figure 10 is the main RF/IF interconnection diagram. This is updated from the original diagram shown in the interconnection document. All the lines shown is this diagram are 0.141 inch semi-rigid cables. This diagram is mainly self-explanatory. The EARS lab junction panel, unit 11, is shown in the lower right of the diagram. The IF output panel is shown directly above it. All the connectors on

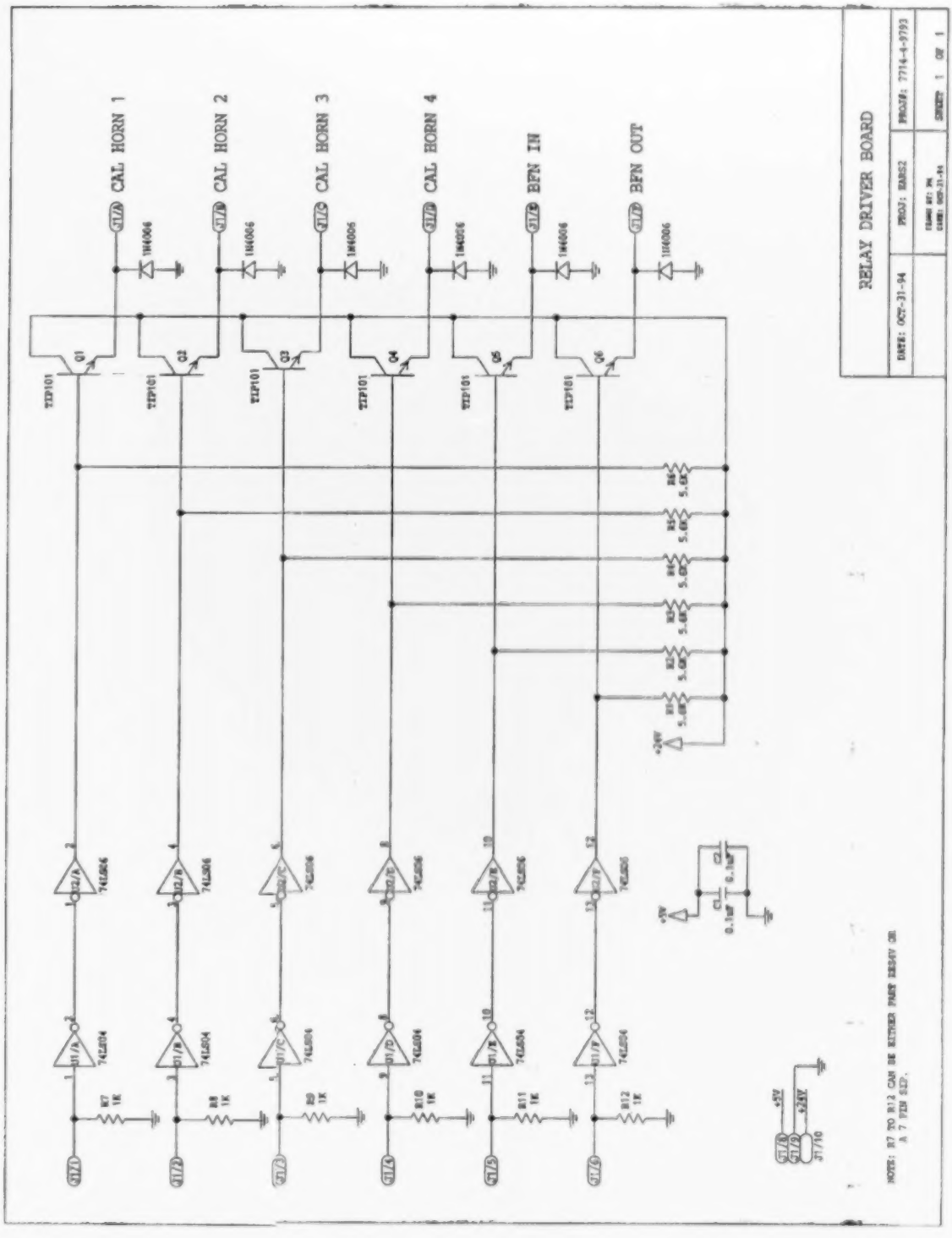


Figure 9
Switch Driver Board Schematic

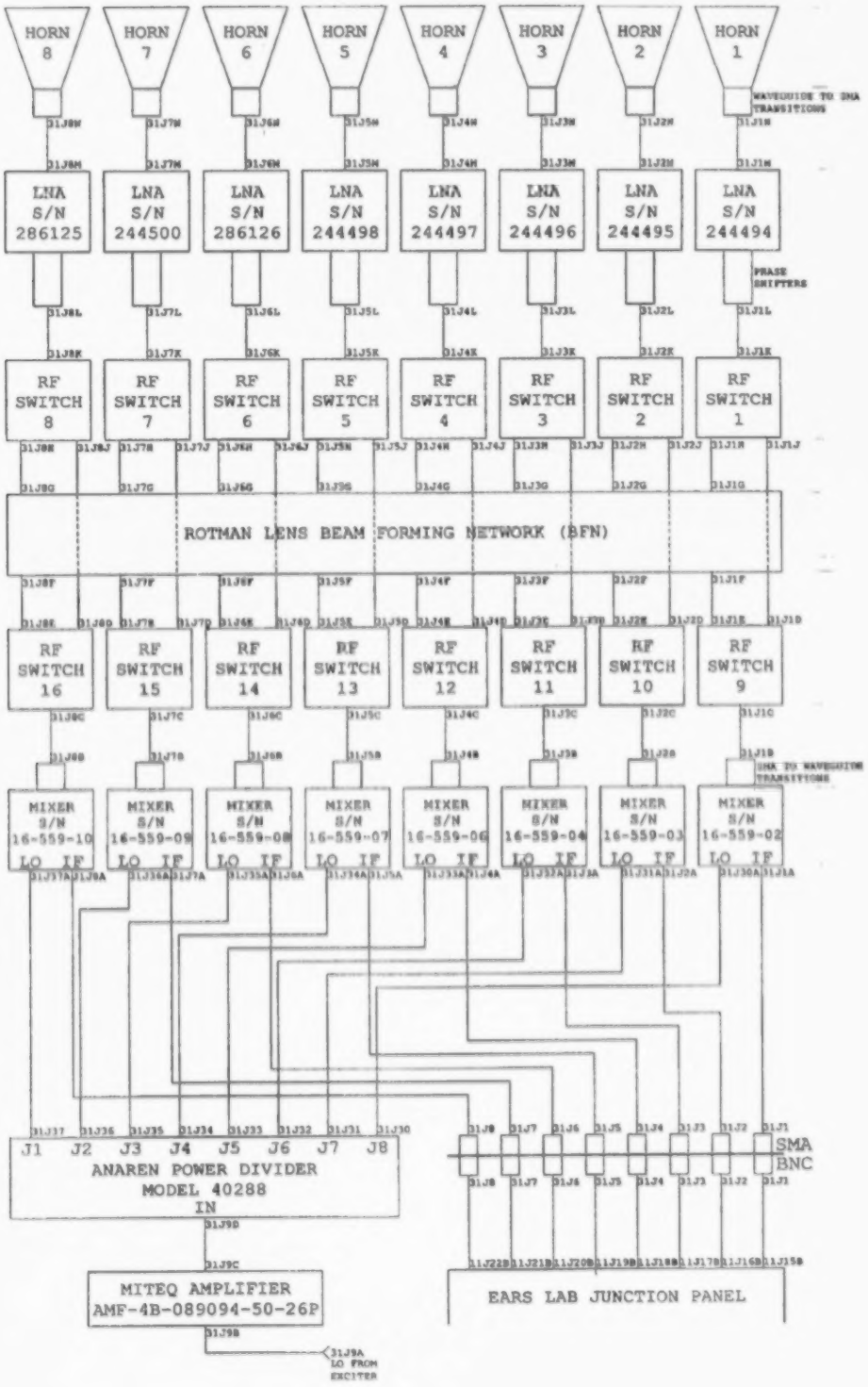


Figure 10
SLC RF/IF Interconnection Diagram

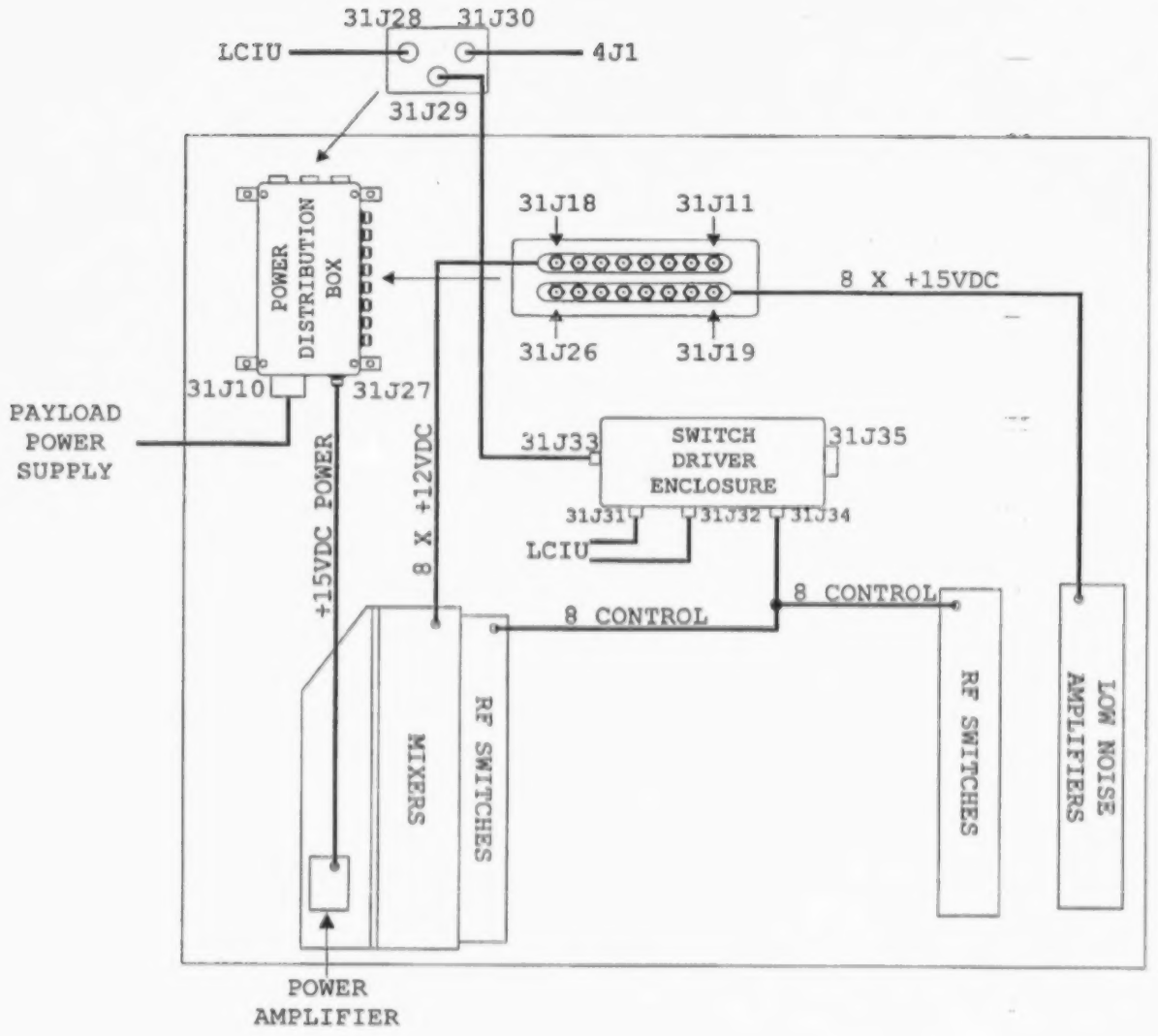


Figure 11

SLC Power and Control Interconnection Diagram

this panel are bulkhead BNC to SMA transitions, except for 31J8, which has SMA connectors on both sides. It is located beside 31J8, although this is not shown in the diagram.

Most of the connections shown in figure 10 are considered internal connections to the SLC array. The only external connections are 31J1 through 31J9. The internal connections are designated with single letter prefixes. The prefixes are assigned along each channel, from the output of the mixer through to the horn. For example, the channel one internal designations start with 31J1A, at the mixer IF output through to 31J1N, at the horn transition output.

The power and control interconnections are shown in figure 11. These connections are shown separate from RF/IF connections since a single interconnection diagram would be too large and complicated. Since the power and control interconnections are mainly hard-wired they generally do not have connector designations assigned to them.

To further explain the SLC array interconnections, the interconnection table and explanations from the EARS interconnection document have been included. There are several common types of connectors used throughout the EARS. The most common connectors have acronyms assigned to them. The most common type of connector used for DC supply voltages and control signals is the military type circular multi-pin connector. This style of connector can either have threads or a bayonet mechanical connection. It can have almost any number of connections and can have pins or pin sockets. By convention, the connector that carries the live signals, such as DC voltages, has the sockets, or is the female type.

The coaxial connections are made using one of two common connectors. The BNC jack (female) chassis, or bulkhead, connector uses a bayonet mount and mates with the plug (male) connector on the coaxial cable. The SMA connector is smaller than the BNC connector and is threaded. The chassis SMA connector is always a jack (female) type. The following acronyms are used for the most common types of connectors.

Acronym	Connector Description
MSBS	circular military style connector, bayonet with sockets, bulkhead mount
MSBP	circular military style connector, bayonet with pins, bulkhead mount
MSTS	circular military style connector, threaded with sockets, bulkhead mount
MSTP	circular military style connector, threaded with pins, bulkhead mount
BNC	BNC type connector, jack bulkhead mount
SMA	SMA type connector, jack bulkhead mount

The following table is taken from the interconnection document and covers all the external connections on the SLC array plate, not including the beacon receiver connections.

CONN. NUMB.	TYPE	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
31J1	BNC	OUT	CHANNEL ONE 60 MHz IF	VARIABLE	11J15B
31J2	BNC	OUT	CHANNEL TWO 60 MHz IF	VARIABLE	11J16B
31J3	BNC	OUT	CHANNEL THREE 60 MHz IF	VARIABLE	11J17B
31J4	BNC	OUT	CHANNEL FOUR 60 MHz IF	VARIABLE	11J18B
31J5	BNC	OUT	CHANNEL FIVE 60 MHz IF	VARIABLE	11J19B
31J6	BNC	OUT	CHANNEL SIX 60 MHz IF	VARIABLE	11J20B
31J7	BNC	OUT	CHANNEL SEVEN 60 MHz IF	VARIABLE	11J21B
31J8	BNC	OUT	CHANNEL EIGHT 60 MHz IF	VARIABLE	11J22B
31J9	BNC	IN	RF LOCAL OSCILLATOR	-7 dBm	2J14

31J10 MSTP type, Amphenol part number 97-3102-20-15P

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	IN	+24 VDC POWER	+24 VDC	3J7-A
B	IN	+15 VDC POWER	+15 VDC	3J7-B
C	IN	+13.5 VDC POWER	+13.5 VDC	3J7-C
D	IN	+12 VDC POWER	+12 VDC	3J7-D
E	IN	+5 VDC POWER	+5 VDC	3J7-E
F	IN	-12 VDC POWER	-12 VDC	3J7-F
G	IN	GROUND	GROUND	3J7-G

CONN. NUMB.	TYPE	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
31J11	SMA	OUT	+12 VDC CHANNEL 1 MIXER SUPPLY	+12 VDC	MIXER 1
31J12	SMA	OUT	+12 VDC CHANNEL 2 MIXER SUPPLY	+12 VDC	MIXER 2
31J13	SMA	OUT	+12 VDC CHANNEL 3 MIXER SUPPLY	+12 VDC	MIXER 3
31J14	SMA	OUT	+12 VDC CHANNEL 4 MIXER SUPPLY	+12 VDC	MIXER 4
31J15	SMA	OUT	+12 VDC CHANNEL 5 MIXER SUPPLY	+12 VDC	MIXER 5
31J16	SMA	OUT	+12 VDC CHANNEL 6 MIXER SUPPLY	+12 VDC	MIXER 6
31J17	SMA	OUT	+12 VDC CHANNEL 7 MIXER SUPPLY	+12 VDC	MIXER 7
31J18	SMA	OUT	+12 VDC CHANNEL 8 MIXER SUPPLY	+12 VDC	MIXER 8
31J19	SMA	OUT	+15 VDC CHANNEL 1 LNA SUPPLY	+15 VDC	LNA 1
31J20	SMA	OUT	+15 VDC CHANNEL 2 LNA SUPPLY	+15 VDC	LNA 2
31J21	SMA	OUT	+15 VDC CHANNEL 3 LNA SUPPLY	+15 VDC	LNA 3
31J22	SMA	OUT	+15 VDC CHANNEL 4 LNA SUPPLY	+15 VDC	LNA 4
31J23	SMA	OUT	+15 VDC CHANNEL 5 LNA SUPPLY	+15 VDC	LNA 5
31J24	SMA	OUT	+15 VDC CHANNEL 6 LNA SUPPLY	+15 VDC	LNA 6
31J25	SMA	OUT	+15 VDC CHANNEL 7 LNA SUPPLY	+15 VDC	LNA 7
31J26	SMA	OUT	+15 VDC CHANNEL 8 LNA SUPPLY	+15 VDC	LNA 8

31J27 SMA OUT +15 VDC LOCAL OSCILLATOR AMPLIFIER +15 VDC LO AMP

31J28 MSBS type, Bendix part number PT02E-8-4S

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	OUT	+15 VDC MONITOR	+15 VDC	10J10-A
B	OUT	+12 VDC MONITOR	+12 VDC	10J10-B
C		GROUND	GROUND	10J10-C
D		Not used		

31J29 MSBS type, Bendix part number PT02E-8-4S

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	OUT	+24 VDC SWITCH POWER	+24 VDC	31J33-A
B	OUT	+5 VDC	+5 VDC	31J33-B
C	OUT	GROUND	GROUND	31J33-C
D		Not used		31J33-D

31J30 MSBS type, Bendix part number PT02E-8-4S

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	OUT	+12 VDC BEACON RECEIVER POWER	+12 VDC	4J1-A
B	OUT	GROUND	GROUND	4J1-B
C	OUT	+15 VDC	+15 VDC	4J1-C
D		Not used		4J1-D

31J31 MSBP type, Bendix part number PT02E-8-4P

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	IN	BFN IN	TTL	10J12-A
B	IN	BFN OUT	TTL	10J12-B
C		Not used		10J12-C
D		Not used		

31J32 MSBP type, Bendix part number PT02E-12-10P

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	IN	FIXED CALIBRATION HORN #1 SELECT	TTL	10J14-A
B	IN	FIXED CALIBRATION HORN HORN #2 SELECT	TTL	10J14-B
C	IN	FIXED CALIBRATION HORN HORN #3 SELECT	TTL	10J14-C
D	IN	MOVING CALIBRATION HORN HORN SELECT	TTL	10J14-D

31J33 MSBP type, Bendix part number PT02E-8-4P

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	IN	+24 VDC	+24 VDC	31J29-A
B	IN	+5 VDC	+5 VDC	31J29-B
C	IN	GROUND	GROUND	31J29-C
D		Not used		———

31J34 MSBS type, Bendix part number PT02E-12-10S

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	OUT	REAR SWITCHES, POS. #2 CONTROL, BFN IN	0/24 V	POS. #2
B	OUT	REAR SWITCHES, POS. #1 CONTROL, BFN OUT	0/24 V	POS. #1
C	OUT	GROUND TO 'COMMON' ON ALL BFN SWITCHES	GROUND	COMMON
D	OUT	FRONT SWITCHES, POS. #2 CONTROL, BFN IN	0/24 V	POS. #2
E	OUT	FRONT SWITCHES, POS. #1 CONTROL, BFN OUT	0/24 V	POS. #1
F	Not used			———
G	Not used			———
H	Not used			———
J	Not used			———
K	Not used			———

31J35 MSBS type, Bendix part number PT02E-12-10S

PIN	DIR.	DESCRIPTION	SIGNAL LEVEL	DESTINATION
A	OUT	CCM FIXED CALIBRATION RADIATOR #1 SELECT	0/24 VDC	PIN 1
B	OUT	CCM FIXED CALIBRATION RADIATOR #2 SELECT	0/24 VDC	PIN 2
C	OUT	CCM FIXED CALIBRATION RADIATOR #3 SELECT	0/24 VDC	PIN 3
D	OUT	CCM MOVING CALIBRATION RADIATOR SELECT	0/24 VDC	PIN 4
E		Not Used		-----
F		Not Used		———
G		Not Used		———
H		Not Used		———
J		Not Used		———
K		Not Used		———

6.0 PERFORMANCE CALCULATIONS

This section presents the bandwidth, noise and dynamic range calculations for the SLC array.

6.1 Bandwidth

The overall system bandwidth is dependent on the bandwidths of the individual system components. Most of the devices such as the horns, LNAs, beam forming network, BFN switches and connections are wideband devices. The most limiting component in the SLC array is the mixer/preamplifier. It sets the three decibel IF bandwidth of the SLC array at 20 megahertz. Filters in the IF receiver further restrict the end-to-end bandwidth to much less than 20 MHz.

6.2 Noise Figure

The front end devices, particularly the LNAs and the orthoguide mixer/preamplifiers determine the absolute noise floor in the system. Each active RF device has a specification called the noise figure (NF), in decibels. The overall noise figure is affected by the individual device noise figures and gains. In the SLC array the two devices that determine the front end noise figure are the LNA and the mixer/preamplifier.

From the table in section 4.2, the minimum gain for all the eight LNAs is 20.3 decibels. The maximum tested LNA noise figure is 1.38. The minimum LNA output power at the one decibel compression point is 14.0 dBm. From the table in section 4.6, the maximum noise figure of all the mixer/preamplifiers is 7.3 decibels. The minimum RF to IF mixer/preamp gain is 23 decibels. These worst case numbers can be used in calculations to determine the overall worst case front end noise figure.

The formula used to calculate a logarithmic value in decibels from a linear number is;

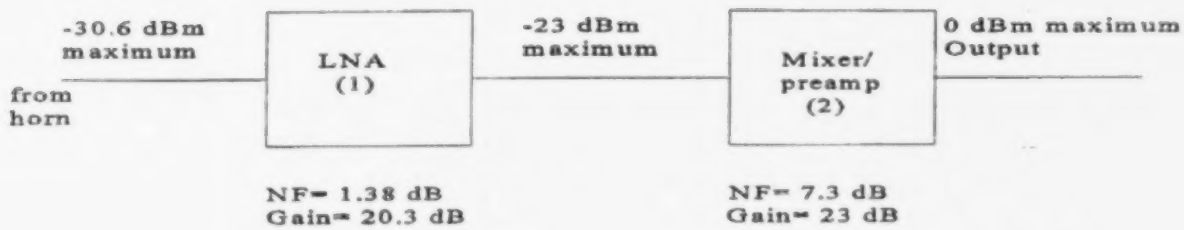
$$Decibel\ Number = 10\ LOG_{10}(Linear\ Number)$$

This equation can be inverted to calculate a linear number from a decibel number.

The front end of the SLC array, without the BFN, is composed of two active devices, the LNA and the mixer/preamp. The passive devices such as the connectors, transitions, switches and cables attenuate the signals and therefore degrade the overall noise figure and dynamic range. Their effect is very minor and will be considered insignificant in these calculations.

The following formula is used to determine the noise figure with two active devices in series;

$$F = F_1 + \frac{F_2 - 1}{G_1}$$



Converting the above logarithmic values to linear numbers,

$$1.38\ \text{dB} = 1.37 = F_1$$
$$7.3\ \text{dB} = 5.37 = F_2$$
$$20.3\ \text{dB} = 107.2 = G_1$$
$$23\ \text{dB} = 199.5 = G_2$$

Substituting the linear values given above,

$$F = 1.37 + \frac{5.37 - 1}{107.2} = 1.41$$

It can be seen that the overall front end noise figure of 1.41, or 1.49 dB, is not much worse than the noise figure of the LNA alone. This is due to the high gain of the LNA.

The main reason a high gain LNA with a low noise figure is useful in the SLC is to overcome the losses encountered when the BFN is added to the front end. The effect of doing this is equivalent to reducing the gain of the LNA by the loss in the BFN. The nominal loss specification of the BFN is ten decibels, therefore, putting the BFN into the system effectively reduces the LNA gain by ten decibels to 10.3 decibels. Using an LNA gain of 10.3 decibels in the above noise figure equation results in a higher noise figure of 1.78 decibels. This is still quite good.

6.3 Dynamic Range

The dynamic range of the system is defined as the difference between the maximum output signal level and the minimum detectable signal level. The maximum level is determined by the one decibel compression point of the RF devices and the saturation levels of the other devices. The minimum useful signal level is the level that can just be detected above the system noise floor. The noise floor is determined almost entirely by the noise in the front end.

To calculate the output noise of an active RF device, the following formula is used;

$$\text{Noise Out} = N_o = F\,k\,T_o\,B_n\,G$$

where F = noise figure = 1.38
k = Boltzman's Constant = 1.38×10^{-23}
T_o = temperature in Kelvin = 273 K + 20°C = 293 K
B_n = bandwidth = 1.5 GHz = 1.5×10^9 Hz
G = Gain = 20.3 dB = 107.2

The noise figure and gain is for the LNA and the calculation is made at room temperature. Running the numbers through the noise equation yields a noise floor of 8.907×10^{-10} watts. Since 0 dBm = 1×10^{-3} watts, 8.907×10^{-10} watts = -60.5 dBm. The maximum LNA output at the one decibel compression point is +14.0 dBm. Therefore the dynamic range is calculated as;

maximum output - noise floor = +14.0 dBm - (-60.5 dBm) = 74.5 dB

A similar calculation can be made for the WM8-12/15C mixer/ preamp. For the mixer/preamp the bandwidth is 20 megahertz, the gain is 199.5 and the noise figure is 5.37. The mixer/preamp calculation yields a noise output of 8.66×10^{-11} watts or -70.6 dBm. Therefore, for the mixer/preamp output,

maximum output - noise floor = 0 dBm - (-70.6 dBm) = 70.6 dB

The noise output from the LNA to the mixer/preamp will be amplified by its gain of 23 decibels. Therefore, the -60.5 dBm noise input to the mixer/preamp will become -37.5 dBm at the IF output of the mixer. The actual dynamic range of the LNA-mixer/preamp combination is only 0 dBm-(-37.5 dBm)= 37.5 dB. The addition of the BFN will reduce the effective gain of the LNA by ten decibels and lower the noise being input to the mixer/preamp by ten decibels. The overall dynamic range will increase to 47.5 dB. Adding the BFN will also allow a ten decibel higher maximum receive signal level.

6.4 Sensitivity

The sensitivity of the system is the minimum signal that can be detected above the system noise floor. The noise is primarily determined by the front end devices. The front end noise is carried through the rest of the system and is added to by the other devices in the system. From the calculations shown above, the output noise of the LNA is -60.5 dBm. With a gain of 20.3 decibels, this equates to an input signal of -80.8 dBm. The gain of the model 640 horn at 9 gigahertz is approximately 15.2 dB. At the input to the horn, the equivalent noise level is -96 dBm. This input signal would just be equivalent to the noise output of the LNA.

For a signal to be detectable, it must generally be at least three decibels above the noise floor. A horn input signal level of -93 dBm should be detectable above the noise of the LNA, assuming no losses in the front end cables or connectors. It is possible to lower the effective noise floor by taking multiple samples of the signal and averaging the samples. For example, digitizing eight samples and averaging them should bring the noise level down by a significant amount.

7.0 TESTING AND CALIBRATION

The SLC array was assembled in building T-80. The array plate and mounting brackets were designed and built by the CRC, with guidance from Applied Silicon personnel. Each individual component was tested and compared to the manufacturer's specifications. Much of the component testing was done using a spectrum analyzer and the HP8410A network analyzer.

The most critical components to assemble and test were the semi-rigid cable assemblies. The cables were made in groups of eight. There are a total of eight groups of eight cables in the entire array. The phase and amplitude characteristics between the groups were not important. It was important to phase match each cable in any group. The eight cables in any group were first cut as close as possible to the same length. SMA connectors were then installed on one end of each cable. The cables were bent to their final installed configuration. The phase of each cable was measured, using a temporary SMA connector on the open end of the cable. The shortest cable was identified and the other cables were physically trimmed in length to match the phase of the shortest cable. Permanent SMA connectors were then installed on the open cable ends. The phase measurements were made one last time before the cables were installed. It is estimated that the cables in any group of eight are phase matched within a ten degree span. The assembly, measurement and testing of the semi-rigid cables was the most time consuming aspect of building the array.

After all the components and cables were mounted on the plate, further testing was done. Each channel was tested end to end, from the cable ends that connect to the horn transitions through to the BNC IF output connectors. Each channel was characterized in phase and amplitude at several frequencies, with all the in-line phase shifters adjusted to their minimum lengths. The phase shifters were adjusted to equalize the phases between the channels. Several iterations were required to bring the channels to within a few degrees of each other. The plate was then installed into the front end rack and the horns on the CCM were connected.

Calibrations of the full array were done using the CCM. It is beyond the scope of this document to describe the array calibrations in detail using the CCM. These calibrations are ongoing and will require the writing of system controller calibration software to complete. The HP8508 vector voltmeter has been used so far to make phase and amplitude measurements. It has required much trial and error to find a good calibration procedure and many calibration iterations. Several important factors have been discovered. The array must be completely stabilized and the temperature has a large effect on the phase readings. It is recommended to have power on the array for at least three hours before taking measurements and to have the array stable in temperature with respect to its environment. The air should be still. A gusty wind can physically change the position

of the CCM radiators with respect to the horns. On a sunny day the entire array should be in the shade, since the heating effect from the sun will change the phase.

APPENDIX A

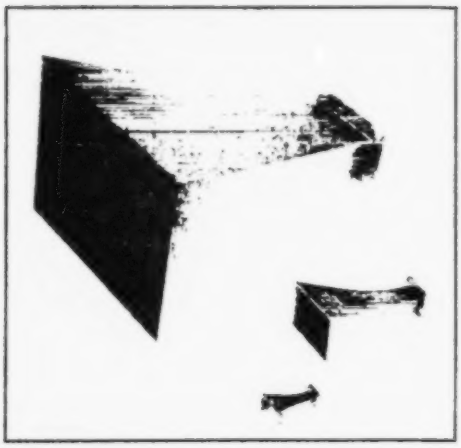
MANUFACTURER'S DATA SHEETS

Horns

1.12-40 GHz

STANDARD GAIN HORNS

- Primary Standard of Antenna Gain
- 10 Models Cover from 1.1 GHz to 40 GHz



SPECIFICATIONS

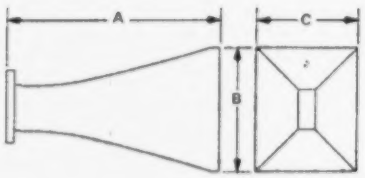
FREQUENCY RANGE (GHz)	MODEL	BAND	WAVEGUIDE SIZE	INPUT FLANGE EQUIVALENT	VSWR (Max)	CON-STRUCTION	WEIGHT lbs.	WEIGHT Kg
1.12-1.7	646	L	WR-650	UG-418A/U	1.25	FA	42	19.1
1.70-2.6	645	LS	WR-430	UG-437A/U	1.25	FA	11	5
2.60-3.95	644	S	WR-284	UG-584/U	1.15	PA	6	2.8
3.95-5.85	643	C	WR-187	UG-407/U	1.15	PA	2.3	1.1
5.4-8.20	642	XN	WR-137	UG-441/U	1.15	PA	1.0	0.5
7.05-10	641	XB	WR-112	UG-138/U	1.15	PA	0.5	0.23
8.20-12.4	640	X	WR-90	UG-135/U	1.15	PA	0.5	0.23
12.4-18	639	KU	WR-62	UG-419/U	1.15	PA	0.2	0.1
18-26.5	638	K	WR-42	UG-595/U	1.15	PB	0.2	0.1
26.5-40	V637	V	WR-28	UG-599/U	1.15	PB	0.1	0.05

FA = Fabricated Aluminum
PA = Precision Aluminum
PB = Precision Bronze
PA = Precision Casting

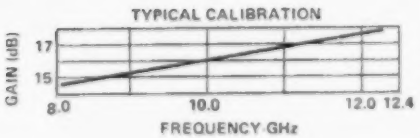
Gain at Mid Frequency and Variation; 16.5 dB with reference to isotropic radiation, variation is 1.5 dB over total band about the mid band value.

LORAL
Microwave-Narda
435 MORELAND ROAD, HAUPPAUGE, NY 11788 • USA TEL: 516 231-1700 • INT'L TEL: (1) 516 231-1390 • FAX (1) 516 231-1

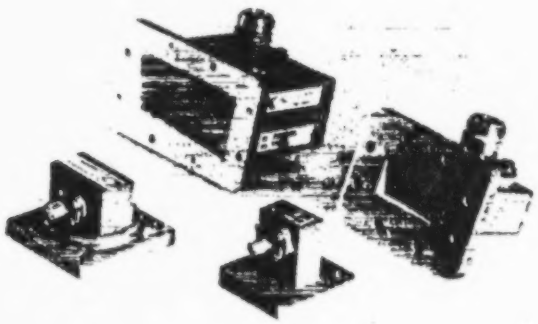
OUTLINE DRAWING



MODEL	A MAX	B MAX	C MAX
V637	1.76 (44.7)	1.06 (26.9)	.82 (20.8)
638	2.57 (65.2)	1.51 (38.3)	1.16 (29.4)
639	3.48 (88.3)	2.20 (55.8)	1.73 (43.9)
640	5.08 (128.5)	3.09 (78.4)	3.34 (59.4)
641	6.31 (160.2)	3.83 (97.2)	2.87 (72.8)
642	7.76 (197.1)	4.67 (118.6)	3.53 (89.6)
643	10.47 (265.9)	6.34 (161.0)	4.80 (121.9)
644	15.82 (401.8)	9.52 (241.8)	7.16 (181.8)
645	16.91 (439.7)	14.24 (361.6)	10.43 (264.9)
646	24.91 (632.7)	21.31 (541.2)	15.88 (403.3)



Waveguide to Coaxial

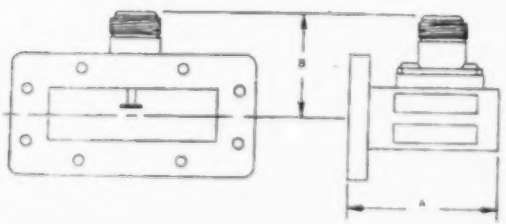


The GHz standard line of **WAVEGUIDE TO COAX ADAPTERS** operate over the full waveguide frequency band from WR284 through WR28 waveguide size.

VSWR performance of 1.05:1 or better is available over moderate bandwidths such as 10%.

WAVEGUIDE TO SMA

Model No.	Waveguide Size	Frequency Range (GHz)	VSWR (max)	Dimensions (inches)	
				A	B
WCA1S	WR284	2.60-3.95		2.50	1.25
WCA2S	WR229	3.30-4.90	1.15	2.25	1.15
WCA3S	WR187	3.95-5.85		1.90	1.00
WCA4S	WR159	4.90-7.05		1.90	0.95
WCA5S	WR137	5.85-8.20		1.50	0.85
WCA6S	WR112	7.05-10.00		1.30	0.80
WCA7S	WR90	8.20-12.40		1.30	0.75
WCA8S	WR75	10.00-15.00	1.20	1.25	0.70
WCA9S	WR62	12.40-18.00		1.25	0.65
WCA10S	WR51	15.00-22.00		1.00	0.65
WCA11S	WR42	18.00-26.50		1.00	0.60
WCA12S	WR28	26.50-40.00	—	—	—



NOTE: 1- Standard components are supplied with CMR flange
2- Other flanges are available upon request

MITEQ

Project P38351

Internal Transfer

Customer P/N

Model AMF-25-085100-20

Serial No. 244494

SPECIFICATIONS

Frequency (GHz)	8.5-10.0 GHz	Output Power (dBm) at 1 dB Compression	+10dBm min
Gain (dB) WINDOW @+25°C	18.0-22.0 dB	Voltage	+15 Vdc.
Gain Flatness (dB)	±1.0dB MAX	IT Measured Current (mA)	43mA
VSWR Input/Output	1.50:1/2.0:1 MAX	OPERATING TEMP:	-40° → +60°C
Noise Figure (dB)	2.0dB MAX		
Noise Temp °K	—		

TEST DATA

Frequency (GHz)	Gain (dB)	VSWR In	VSWR Out	N. F. dB	Noise temp °K	Po at 1dB comp.	Po hard satu.
8.5	SEE	1.19:1	1.85:1	1.22	—	13.8	
9.0	ATTACHED	MAX	MAX	1.26	—	14.4	
9.5	GRAPH	↓	↓	1.32	—	14.1	
10.0	↓	↓	↓	1.37	—	14.0	

Tested By M. Liotta Date 2/25/92

MITEQ INC. • 100 Davids Drive • Hauppauge, New York 11788-2086 • Tel. (516)436-7400

MITEQ

Project P38351

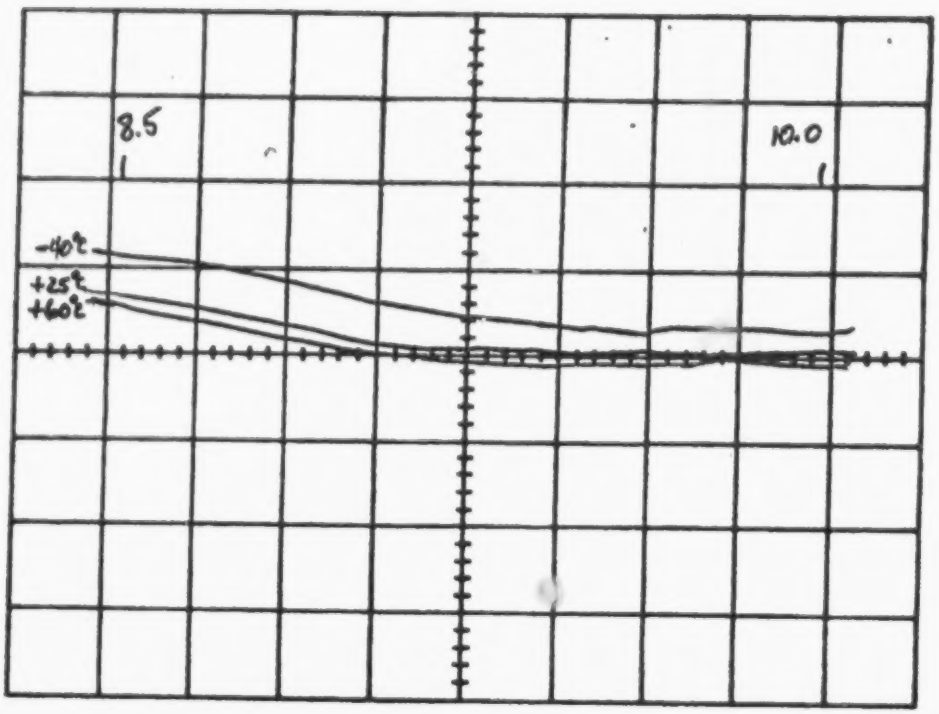
Internal Transfer

Customer P/N

Model AMF-2S-085100-20

Serial No. 244494

GAIN BANDWIDTH



Tested By M. Liotta Date 2/25/98

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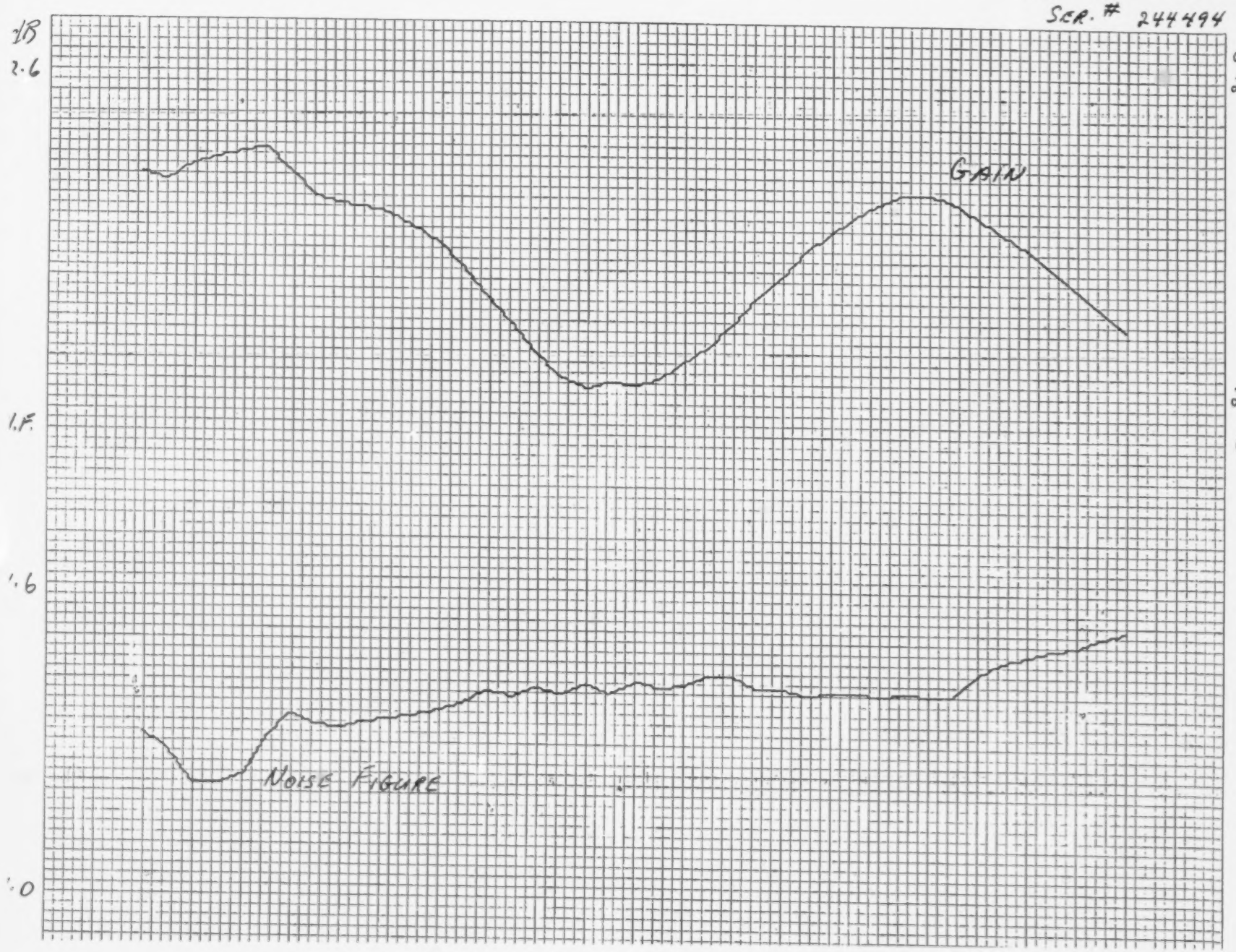
K·E 5 X 5 TO THE CENTIMETER 18 X 24 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.

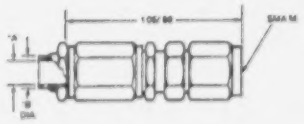
AMF-2S-085100-20
SER. # 244494



Refer to Assembly Instructions 103 and 104 on pages 87 and 88.

Phase Adjustable SMA Connector

CDI Part No.	"A"	Cable Type
5999-1CCSF	.143 min.	.141
5999-2CCSF	.088 min.	.085



Physical length change per revolution of adjustment nut: .018 inch
Electrical length change per revolution of adjustment nut: .0127
Max. change in physical length: .160 ± .010 inch of air.
Max. change in electrical length: .113 ± .007 inch of teflon.

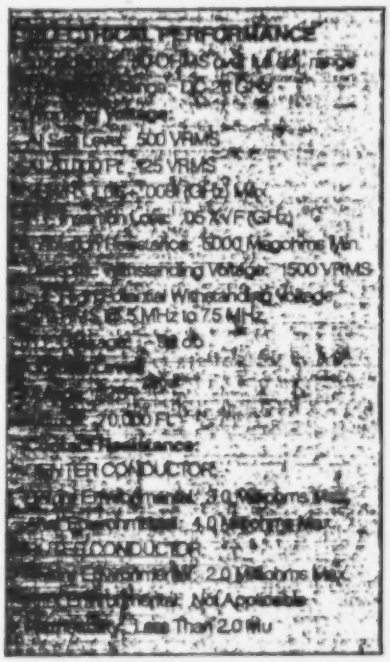
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	53°	63°	10°	1.09°
4	106°	126°	20°	2.19°
6	159°	189°	29°	3.29°
8	212°	252°	39°	4.39°
10	265°	315°	49°	5.49°
12	318°	378°	59°	6.58°
14	371°	442°	68°	7.68°
16	424°	505°	78°	8.78°
18	477°	568°	88°	9.87°
20	530°	630°	97°	10.95°
22	583°	694°	107°	11.38°
24	636°	757°	117°	13.14°
26	689°	820°	127°	14.23°

Standard units are passivated; "A" & "B" diameters will be gold plated for solderability.
Center contact is captivated.

DESCRIPTION

The CDI 5999 is an adjustable coaxial phase shifter, covering DC through 26 GHz. Inserting this device into a cable/connector line provides continuously variable phase shift (up to 126deg. at 26 GHz) allowing adjustment of the electrical separation between the other components in a system.

Made of passivated stainless steel, the 5999 incorporates an SMA Male connector, spacing assembly, and a positive, resettable locking mechanism.



Refer to Assembly Instructions 178 and 179 on pages 114 and 115.

Refer to Assembly Instructions 103 and 104 on pages 87 and 88.

Phase Adjustable SMA Connector

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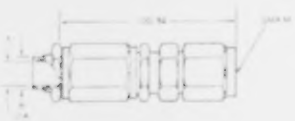
5999-1CCSF	.143 min.	.141
5999-2CCSF	.088 min.	.085



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22	583°	694°	107°	11.38°
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DESCRIPTION

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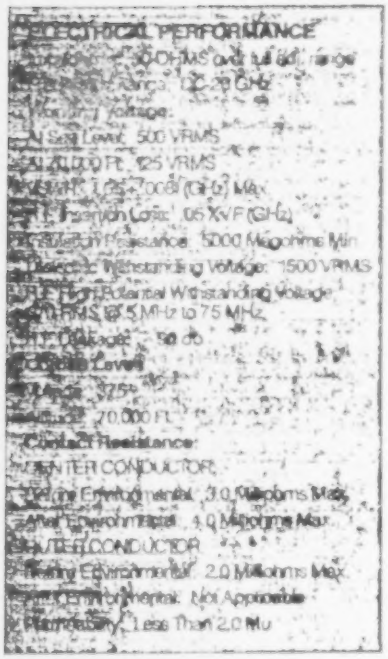
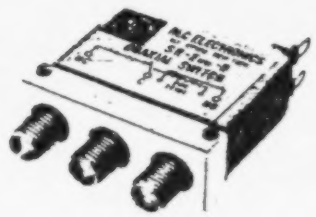


Refer to Assembly Instructions 178 and 179 on pages 114 and 115.

Miniature Coaxial Switches



This RLC Electronics Miniature Coaxial Switch is a single pole, two position type. The switch provides extremely high reliability, long life and excellent electrical performance characteristics over the frequency range of DC-18.0 GHz with options to 26.5 GHz and 40 GHz. The miniature package utilizes high density packaging techniques, hence the overall volume of the switch is less than ¾ cubic inch. The switch is available in the following configurations — manual or remote, inboard or outboard mounting holes, 12 Vdc, 28 Vdc or 115 Vac operation, with or without indicator terminals, failsafe or latching cutthroat, with or without TTL drivers.

Specifications

S^{1}-2$_{MIN}^{2}$-^{3}-^{4}-^{5}-^{6}-^{7}

Switch Type	Single Pole Two Position								
Frequency Range	DC-18 GHz			26.5 Opt.	40 GHz Option				
Frequency (GHz)	DC-4	4-12.4	12.4-18	18-26.5	DC-6	6-12	12-18	18-26.5	26.5-40
Insertion Loss (Max)	0.1 dB	0.2 dB	0.3 dB	1.0 dB	0.2 dB	0.4 dB	0.5 dB	0.7 dB	0.9 dB
VSWR (Max)	1.2:1	1.3:1	1.5:1	1.65:1	1.3:1	1.4:1	1.5:1	1.7:1	1.9:1
Isolation (Min)	80 dB	70 dB	60 dB	40 dB	70 dB	60 dB	60 dB	55 dB	50 dB

Power Rating, RF, Cold Switching: See page 5.
Impedance: 50 ohms.
Operating Power 25 °C:
(Failsafe): 12 Vdc at 250 ma nom.
28 Vdc at 140 ma nom. 115 Vac at 50 ma nom.
(Latching): 12 Vdc at 120 ma nom. 28 Vdc at 42 ma nom. 115 Vac at 43 ma nom. Current applied 10 ms min.; cut throat standard, recovery time 100 ms nom.

Connectors, RF: SMA Female.
Connectors, Power: Feed through solder lugs.
Life: 1,000,000 operations.
Switching Time: 15 milliseconds max.
Weight: 2 oz.
Environmental Conditions: MIL-S-3928
Operating Mode: Manual, failsafe or latching.
Switching Sequence: Break before make.

To designate the switch desired use:

(1) "M" for Manual, "R" for Remote.
(2) "Min" for outboard mountings or "Minin" for inboard mountings.
(3) "A" for 115 Vac, "D" for 28 Vdc or "H" for 12 Vdc.
(4) "I" for Indicators if desired.
(5) "L" for latching cut throat if desired.
(6) "TL" for TTL Driver if desired.
(7) "26" for 26.5 GHz option.
(8) Arc Supression diodes.

Example: SR-2 MIN-D is a remote, outboard mounting, 28 Vdc, failsafe switch, for DC to 18 GHz use.

Specials requiring closer tolerances, different frequency ranges, special connectors, different materials, finishes, etc., can be furnished upon request.

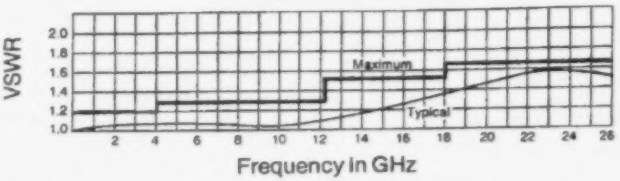
Specifications subject to change without notice.

RLC ELECTRONICS, INC.

Typical Operating Curves

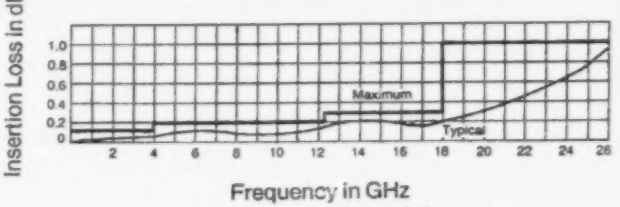
DC-18 & DC-26 GHz Switches

VSWR Vs. Frequency



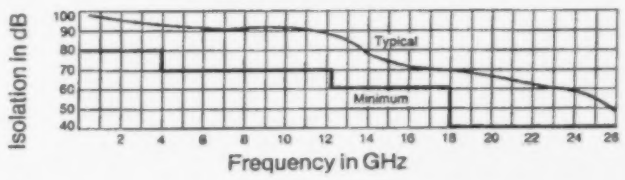
Frequency in GHz

Insertion Loss Vs. Frequency



Frequency in GHz

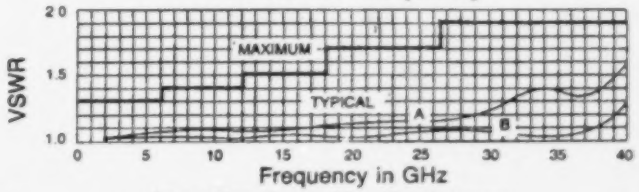
Isolation Vs. Frequency



Frequency in GHz

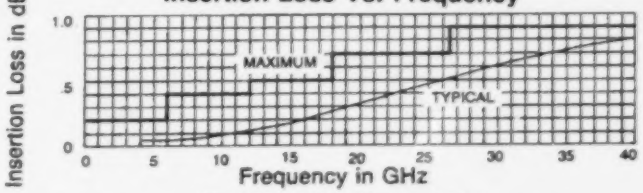
DC-40 GHz Switches

VSWR Vs. Frequency



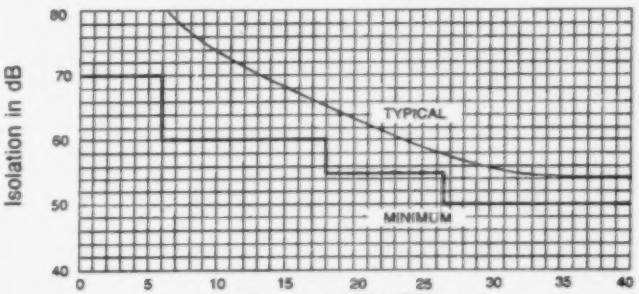
Frequency in GHz

Insertion Loss Vs. Frequency



Frequency in GHz

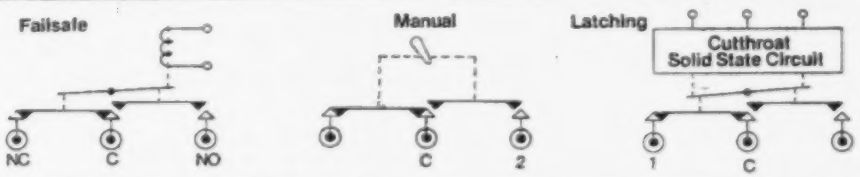
Isolation Vs. Frequency



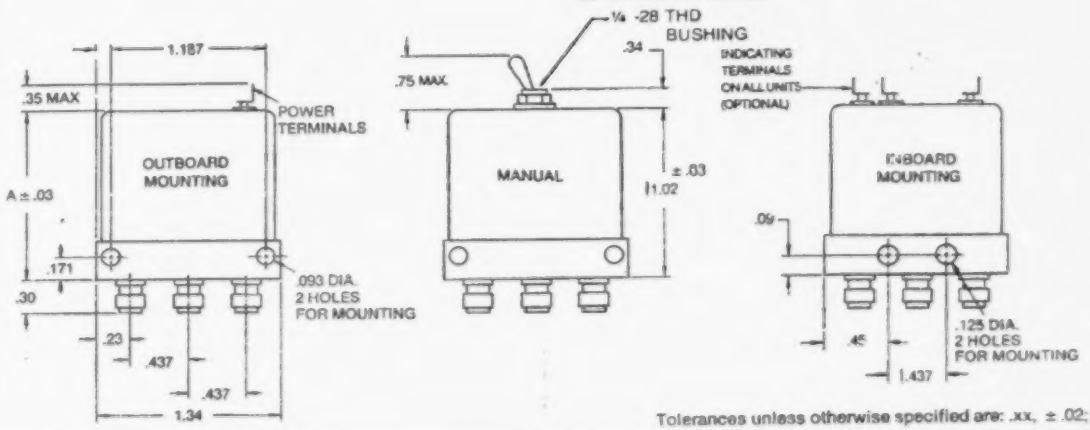
Frequency in GHz

A = SR-2 Min IN-D-40 with Connectors
B = Two Connectors Back to Back

Schematics



Outlines

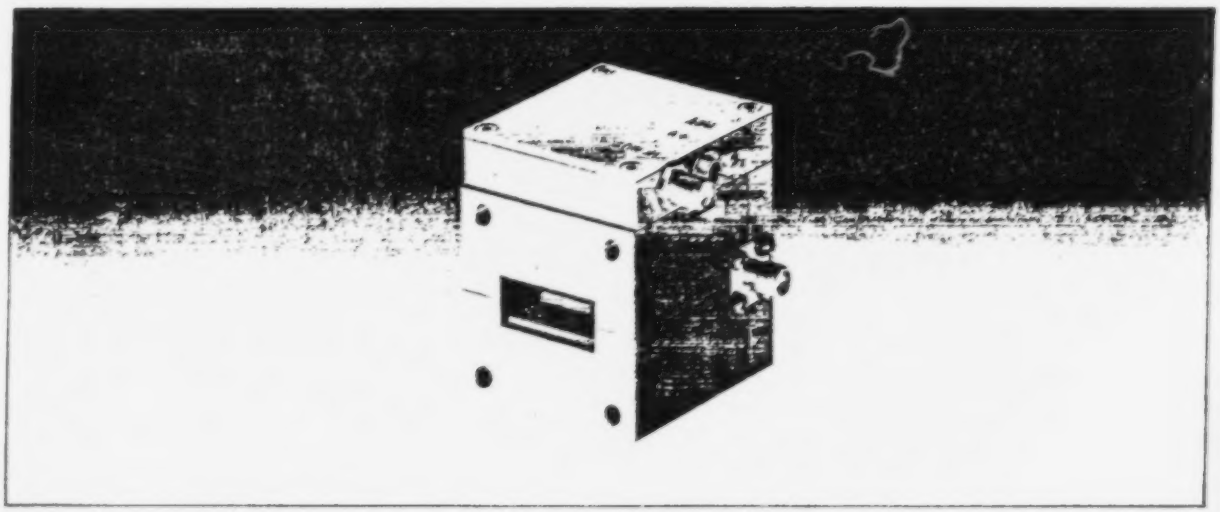


MODEL NO.	A
SR-2 Min-D	1.18
SR-2Min-D-I	1.59
SR-2Min-D-L	1.80
SR-2Min-D-I-L	1.87
SR-2Min-D-TL	1.87
SR-2Min-D-I-TL	1.87
SR-2Min-D-H-L-TL	1.87
Add to Above For 115 VAC	.42
2 Minin and 2 Min-H Units same as 2 Min	
Width of all units .500 in	

Tolerances unless otherwise specified are: .xx, ± .02; .xxx, ± .005.

Orthoguide Mixers and Mixer Preamps

■ 8 thru 18 GHz



The development of the Orthoguide waveguide mixer series is a result of RHG's extensive experience in MIC mixer design and sophisticated waveguide techniques. The WM waveguide mixer and mixer pre-amp series combine the advantages of waveguide and microstrip technology in unique designs that advance the start-of-the-art and offer superior performance for a wide range of applications.

The RF input for the orthoguide designs has been kept in waveguide for minimum loss, and the LO input is an SMA coax connector. This combination is ideal both for developing new systems, and for upgrading older systems since it is compatible with existing waveguide RF inputs and most LO's.

Microwave IF models are available featuring an extraordinary IF response (DC to greater than 4 GHz at X-band and 6 GHz at Ku Band). The Orthoguide series' excellent conversion efficiency and flatness is maintained even at these microwave IF's. The microwave IF response is ideal for use in the first IF in channelized receiver systems, and in telemetry applications.

MIXERS WITHOUT PREAMPS

Model No.	RF/LO Frequency (GHz)	IF Response	Diode Configuration[4]	Conversion Loss Typ. (dB)	Conversion Loss Max. (dB)	Price
WM8-12	8 to 12	DC to 400 MHz	DA9.0	5.0	6.5	$695
WM12-18	12 to 18	DC to 400 MHz	DA12-18	5.5	7.0	745
WM8-12A	8 to 12	DC to 4 GHz	DA8-12H	5.5	7.0	795
WM12-18A	12 to 18	DC to 6 GHz	DA12-18H	6.0	7.5	845

INTEGRATED MIXER PREAMPS

Model No.	RF/LO Coverage (GHz)	IF Output at 1 dB Compression (dBm)	IF Freq/BW (MHz)	Diode Config.[4]	Overall SSB NF[3] Typ. (dB)	Overall SSB NF[3] Max. (dB)	Min. RF/IF Gain (dB)	Price
WM8-12/15A	8 to 12	0	60/10	DA9.0	6.5	7.7	20	$1195
WM8-12/15B	8 to 12	0	60/20	DA9.0	6.5	7.7	20	1195
WM8-12/15C	8 to 12	0	30/10	DA9.0	6.5	7.7	20	1195
WM8-12/14EF	8 to 12	+ 13	160/40	DA9.0	7.0	8.5	20	1295
WM12-18/15A	12 to 18	0	60/10	DA12-18	6.7	8.0	20	1295
WM12-18/15B	12 to 18	0	60/20	DA12-18	6.7	8.0	20	1295
WM12-18/15C	12 to 18	0	30/10	DA12-18	6.7	8.0	20	1295
WM12-18/14EF	12 to 18	+ 13	160/40	DA12-18	7.2	8.7	20	1395

(continued on next page) ►

MICROWAVE IF MODELS				
Model No.	RF Coverage (GHz)	IF Coverage (MHz)	Noise Figure (dB)*	Price
WM8-12/30A	8-12	200-400	6.5	$1310
WM12-18/30A	12-18	200-400	7.0	1420
WM8-12/45A	8-12	300-600	6.5	1365
WM12-18/45A	12-18	300-600	7.0	1475
WM8-12/70A	8-12	600-800	7.0	1365
WM12-18/70A	12-18	600-800	7.5	1475
WM8-12/100A	8-12	900-1100	7.0	1395
WM12-18/100A	12-18	900-1100	7.5	1505
WM8-12/150A	8-12	1400-1600	7.5	1420
WM12-18/150A	12-18	1400-1600	8.0	1530

ADDITIONAL SPECIFICATIONS:

(All Models)

1. LO Power: +8 dBm (typ) all models
2. RF-LO Isolation: 20 dB (typ)
3. RF VSWR: less than 2.0:1
   LO VSWR: less than 3.5:1
4. Outline drawings: See page 71.
5. Weight: X-Band - 265 g (9.3 oz) max.
   Ku-Band - 155 g (5.5 oz) max.

NOTES:

(All models)

1. All models are designed to meet MIL-E-5400, Class II requirements, with temperature range of −54°C to +71°C.
2. The WM Series provides excellent performance when used as an harmonic mode mixer. Consult factory for details.
3. All noise figures are SSB, (mid band RF/IF). Typical variation over temperature range is ± 0.3 dB.
4. Max. total power input to mixer:
   CW: +20 dBm
   Peak pulse power: 0.1 ergs (for pulses <50ns)
5. DC Power for mixer preamps: +12 V at 30 mA (typ) all models except 60 mA (typ) for 14EF preamp. (For +15 V add suffix "C", no charge).
6. See instructions for ordering diode replacements.

DIODE REPLACEMENT:

The RHG Orthoguide Mixer WM Series incorporates a user replaceable diode structure. Under normal operation, no maintenance or replacement is required. However, in radar systems, TR or limiter failures may result in very high power levels which may cause severe damage to the diodes.

Diode replacement is achieved simply by disassembling the mixer and substituting a new microstrip board assembly containing a new diode structure. Complete instructions are provided with each replacement board assembly.

To Order Diodes

Replacement diode assemblies may be ordered by the diode configuration number shown in the chart. For mixers incorporating Option 2 or 3, contact factory for details.

OPTIONS:

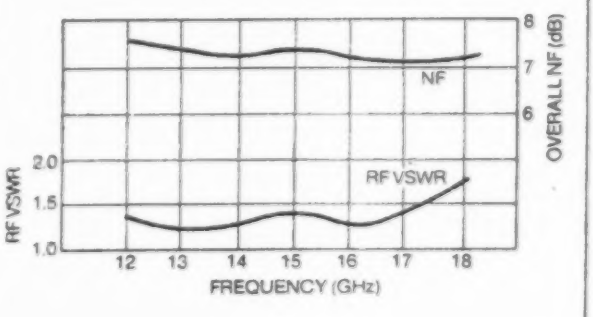
(For Models with IF <160 MHz)

1. Gain controllable preamps available for 30 and 60 MHz models:
   a. 20 dB control for −3 V bias input: add suffix "G" and $40.
   b. 20 dB control with gain and phase tracking of ±1 dB and ±5°: add suffix "GM" and $125.
   c. Gain controlled models will have a 1 dB (nom) higher noise figure than standard models.
2. DC isolated mixer diodes allow monitoring of crystal currents: add suffix "B" and $150 (NF degrades approx. 1.0 dB). Not available for IF >160 MHz.
3. Starved LO configuration for LO injection levels to −10 dBm (at increased NF). Diodes are DC isolated (as in Option 2) with built-in protective biasing network. Use +12 VDC bias. Contact factory.
4. IF preamp frequency/BW combinations of 6 GHz available. Contact factory for details. See charge below for standard IF models.

Preamp Type	Center Frequency (MHz)	Bandwidth (MHz min)	RF-IF Gain (dB min)	*Add'l N.F.	*Add'l Cost
10KK	10	2	25	1.0	$75
10LL	20	6	25	0.5	75
10D	70	10	25	0.5	75
10JJ	70	30	25	0.5	75
10BB	120	20	25	1.5	75
10DD	130	50	25	1.5	75
10HH	(10 to 200)		20	1.5	100

* Added to the values shown for "15A" mixer preamp type.

TYPICAL NOISE FIGURE & RF VSWR FOR WM12-18/15C MIXER PREAMP



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MITEQ

Project P50P85

Internal Transfer _____

Customer P/N _____

Model AMF-4T5-089094-50-26P

Serial No. 540976

SPECIFICATIONS

Frequency (GHz)	8.90-9.40GHz	Output Power (dBm) @ 1 dB Compression	+26dBm min
Gain (dB)	25.0dB min	Voltage	+15Vdc
Gain Flatness (dB)	±1.0dB max	I_T Measured Current (mA)	416mA
VSWR Input/Output	2.0:1 max	Pin Max (dBm)	+4.9dBm
Noise Figure (dB)	5.0dB max		
Noise Temp °K	—		

TEST DATA

Frequency (GHz)	Gain (dB)	VSWR In	VSWR Out	N.F. (dB)	Noise Temp °K	Po (dBm) @ 1dB comp	Po (dBm) hard satu.
8.90	see	1.79:1	1.15:1	4.14	—	+26.2	—
9.150	att.	max	max	4.45	—	+26.3	—
9.40	plot	↓	↓	4.73	—	+26.3	—

Tested By Mike Maerki Date JUL 20 1994

MITEQ Inc. * 100 Davids Dr. * Hauppauge, New York 11788-2086 * Tel (516)-436-7400

MITEQ

Project P50 APS

Internal Transfer

Customer P/N

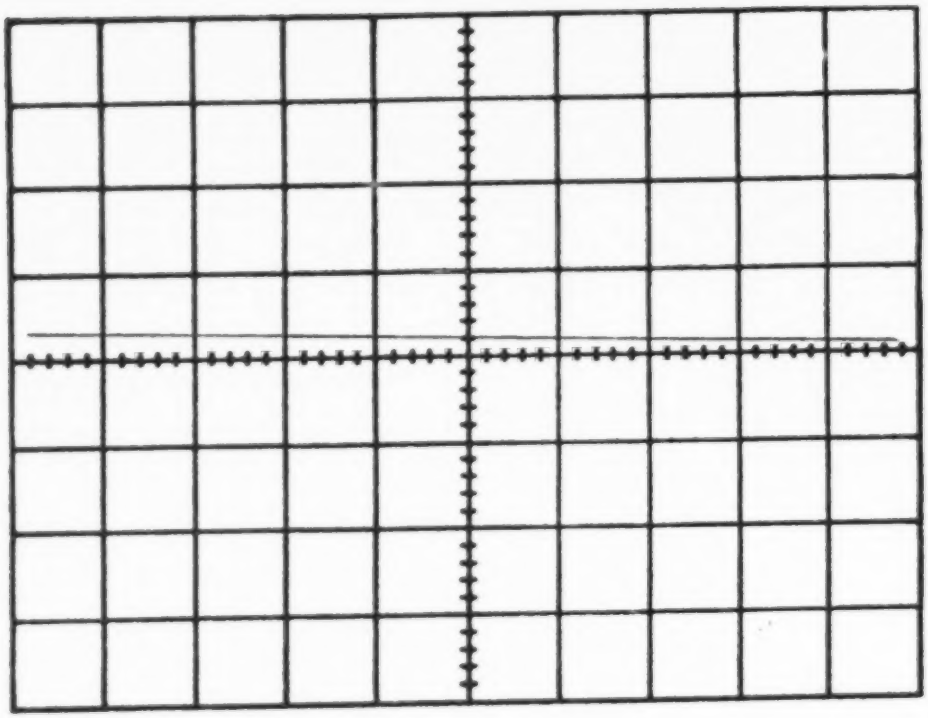
Model AMF-4B-0P9094-50-26P

Serial No. 540976

GAIN BANDWIDTH

8.9
1

9.4
1



Tested By Mike Marini

Date JUL 20 1994

MITEQ INC. • 100 Davids Drive • Hauppauge, New York 11788-2086 • Tel. (516)436-7400

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2. CURNOW, John *SIDE-LOBE CANCELLER ARRAY DESIGN **INTERCONNECTION DOCUMENT,*** Applied Silicon Inc. Canada, Nov. 1992, Rev. 2.0

3. CURNOW, John PABLO-DURA, Manuel MOORE, Robert CARON, Gilles *EXPERIMENTAL ARRAY RADAR SYSTEM **SYSTEM INTERCONNECTIONS***, Applied Silicon Inc. Canada, April 1996, Rev. 1.0

ABBREVIATIONS

BFN	Beam Forming Network
CCM	Calibration Control Mechanism
dB	decibel
DREO	Defence Research Establishment Ottawa
EARS	Experimental Array Radar System
IF	Intermediate Frequency
LNA	Low Noise Amplifier
LO	Local Oscillator
NF	Noise Figure
PRF	Pulse Repetition Frequency
RF	Radio Frequency
SLC	Side Lobe Canceller
TTL	Transistor Transistor Logic
TWTA	Travelling Wave Tube Amplifier
VDC	Volts Direct Current
VSWR	Voltage Standing Wave Ratio

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3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C or U) in parentheses after the title.)

SIDE-LOBE CANCELLER ARRAY DESIGN DESCRIPTION

4. AUTHORS (Last name, first name, middle initial)

CURNOW, JOHN W.

5. DATE OF PUBLICATION (month and year of publication of document)

APRIL 1996

6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)

47

6b. NO. OF REFS (total cited i document)

3

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type c report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

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8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

DND - DEFENCE RESEARCH ESTABLISHMENT OTTAWA
RADAR AND SPACE DIVISION (SURFACE RADAR)
SHIRLEY'S BAY, OTTAWA, ONTARIO

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EARS RADAR RESEARCH PROJECT

9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)

W7714-5-9868

10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)

974-55126-07

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This document presents a detailed hardware and operational description of the Side-Lobe Canceller (SLC) Array. This array is one of two eight element arrays in the Experimental Array Radar System (EARS). It has eight standard gain horns oriented in a horizontal line using horizontal polarization. This report presents a short description of the EARS and how the SLC array is used in the system. The SLC is described in detail, beginning with a general description and continuing with more detailed information. This document was prepared under task 6.3 of contract number W7714-5-9868. A major re-build of the array was done in early 1995, without documentation. The two original documents covering the SLC array have been used as the basis for this document, with updates. A related document has been prepared covering the Calibration Control Mechanism (CCM). This is a frame with four radiators on it that is used to calibrate the SLC array, located immediately in front of the SLC array. The array horns are mounted on the rear of the CCM frame and the remainder of the array is mounted on a large plate which is located near the top of the front end platform equipment rack.

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BFN	Beam Forming Network
CCM	Calibration Control Mechanism
dB	decibel
DREO	Defence Research Establishment Ottawa
EARS	Experimental Array Radar System
IF	Intermediate Frequency
LNA	Low Noise Amplifier
LO	Local Oscillator
NF	Noise Figure
PRF	Pulse Repetition Frequency
RF	Radio Frequency
SLC	Side Lobe Canceller
TTL	Transistor Transistor Logic
TWTA	Travelling Wave Tube Amplifier
VDC	Volts Direct Current
VSWR	Voltage Standing Wave Ratio